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LA REPORT-444

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October 31, 1945

This document contains 7 pages

# MEASUREMENT OF THE SLOW-NEUTRON FISSION CROSS SECTION OF $Pu^{240}$



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## ABSTRACT

The ratio of the slow-neutron fission cross sections of $Pu^{240}$ and $Pu^{239}$ is

$$\frac{\sigma_f(40)}{\sigma_f(49)} = 0.09 \pm 0.33$$


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## MEASUREMENT OF THE SLOW-NEUTRON FISSION CROSS SECTION OF $Pu^{240}$

In March, 1945, two samples of Pu containing different amounts (0.0 percent and 0.65 percent) of $Pu^{240}$ were compared by alpha count, and again by fission count when placed in the same slow-neutron flux. Results were not conclusive, but the indication was that $Pu^{240}$ was an alpha emitter of shorter half-life than $Pu^{239}$, or that $Pu^{240}$ had a smaller slow-neutron cross section, or both.

Pu of higher $Pu^{240}$ content has become available, and several determinations of the half-life of $Pu^{240}$ have been made. The experiment has been repeated, using more highly enriched Pu, in order to make an approximate determination of the fission cross section of $Pu^{240}$.

Two pairs of samples were prepared, samples "C-24," containing about 0.05 percent $Pu^{240}$, and samples "CW-2," (of Hanford reirradiated material) containing about 4 percent $Pu^{240}$. The samples were prepared as follows:

Solutions of plutonium 1N in HCl, containing approximately one microgram of plutonium per ml, were prepared and stored in quartz vessels. Quartz-distilled water and quartz-distilled HCl used were furnished by Wickers. About twenty microliters of the plutonium solution were spread in the form of fine droplets over a 2-cm-diameter circle on a platinum disc. These droplets were then evaporated under a heat lamp. This process was repeated until the desired amount of plutonium was deposited on the platinum disc. At frequent intervals during the process the platinum disc was ignited in a flame. The total volume evaporated per plate was of the order of one ml, and the Pu deposited was of the order of one-half μg. The resulting plates were practically invisible, and completely transparent to fission fragments.

$\sigma_f(40)/\sigma_f(49)$ can be computed as follows from a comparison of two samples 1 and 2 of different $Pu^{240}$ content:



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$$\sigma_f(40)/\sigma_f(49) = (1/F_2)\,(N_2/N_1)\,(S_2/S_1)\,(\alpha_1/\alpha_2) - (1-F_2)/F_2$$

where

$F_2$ is the ratio of $Pu^{240}/Pu$ in sample 1;

$N_1$ and $N_2$ are the fission counting rates of samples 1 and 2, respectively, when placed in the same slow-neutron flux;

$S_1$ and $S_2$ are the specific alpha activities of materials 1 and 2 from which the samples are made;

$\alpha_1$ and $\alpha_2$ are the alpha counting rates of samples 1 and 2; and where material 1 has a $Pu^{240}/Pu$ ratio $F_1$ which is essentially zero, as is the case for the "C-24" samples used in the experiment.

$F_1$ and $F_2$ were determined by spontaneous fission measurements and were found to be $F_1 = 0.0005 \pm 0.0001$ (C-24) and $F_2 = 0.0404 \pm 0.002$ (CW-2).

The ratio $N_2/N_1$ was determined by placing two samples of approximately equal weight ( $\sim$ 0.7 μg in one determination and $\sim$ 0.5 μg in a second determination) in a comparison chamber, irradiating the samples with slow neutrons, and counting the fissions occurring in each sample. The comparison chamber was an argon-filled flat cylindrical steel chamber in which the samples were mounted back to back on a central electrode at a potential of about -500 volts. Collecting electrodes opposite each sample and about 1 cm distant from the central electrode were connected to twin linear amplifiers and counting circuits. The chamber was placed in the graphite column of the water boiler at Omega, at a point at which the cadmium ratio was about 2000. With the water boiler operating at 1 to 2 KW, counting rates of about 20,000 fissions per minute were obtained. Fission counts were taken at three different biases on the fission plateau and the extrapolated counting rates were used in the calculations. In order to avoid any errors due to differences in chamber geometry or amplifier characteristics two runs were made with each pair of samples, the second run being made with sample positions interchanged.

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Alpha counts were made directly in an argon chamber connected to a fast amplifier and scale of 256.

The specific alpha activities $S_1$ and $S_2$ were calculated on the basis of half-lives of 24,400 and 6,300 years for $Pu^{239}$ and $Pu^{240}$, respectively, corresponding to specific activities of 136,000 and 529,000 alpha disintegrations per minute per microgram[1).]

Experimental data and calculated results are as follows:

| | First Determination | Second Determination |
|---|---|---|
| Sample 1 | C-24-1 | C-24-3 |
| Sample 2 | CW2-1 | CW2-3 |
| $F_1$ | 0.0005 | 0.0005 |
| $F_2$ | 0.0404 ± 0.002 | 0.0404 ± 0.002 |
| $S_1$ | 136,200 disintegrations/min x μg | 136,200 |
| $S_2$ | 151,900 " " " | 151,900 |
| $N_1$ | 21,420 ± 70 fission counts/min | 24,700 ± 70 |
| $N_2$ | 19,410 ± 70 " " | 20,050 ± 70 |
| $a_1$ | 51,780 ± 100 alpha counts/min | 34,730 ± 100 |
| $a_2$ | 54,130 ± 100 " " | 32,780 ± 100 |

$\sigma_f(40)/\sigma_f(49) = 0.18$ $\sigma_f(40)/\sigma_f(49) = -0.01$

Average value for $\sigma_f(40)/\sigma_f(49) = 0.09 \pm 0.33$

1) Farwell, Roberts, and Wahl, LAMS-293

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Seaborg, in a letter to Allison, has reported that similar experiments performed at Chicago gave values for $\sigma_f(40)$ of zero and $(1/6)\sigma_f(49)$ ; these results are in reasonable agreement with the results obtained here.

The results do not take into account the possible contribution of $Pu^{241}$ to the slow neutron fission counts. This contribution is probably small, as may be seen from the following reasoning:

Suppose $\sigma_f(40) \simeq (1/10)\sigma_f(49)$

$$\sigma_f(41) = \sigma_f(49)$$

$$\sigma_c(40) = \sigma_c(49)$$

The amount of 40 in the reirradiated 49 is about 4 percent. Then the amount of 41 in 40 would be about 2 percent, assuming no decay of 41. The increment in the experimental value of $\sigma_f(40)/\sigma_f(49)$ caused by the presence of 41 would then be of the order of 2 percent, making no observable difference in the experimental results. However, assignment of values to $\sigma_c(40)$ and $\sigma_f(41)$ which are several times the corresponding cross sections of 49 would indicate that $\sigma_f(40)$ is zero and the apparent fission of 40 is due entirely to 41.

The uncertainty in the half-life of $Pu^{240}$ (about 10 percent) introduces the largest single error in the experiment. A direct determination of the specific activity $S_2$ of the enriched material, accurate to $\pm$ 1/2 percent, would bring the error due to the uncertainty in $S_2$ down to the level of the other experimental errors involved, and bring the overall probable error in $\sigma_f(40)/\sigma_f(49)$ down to $\pm$ 0.2. Such an analysis is difficult with the very small amount of reirradiated material available for the experiment. A more precise determination of the half-life of $Pu^{240}$, if it should be made, will improve the accuracy of the experiment. A change of + 5 percent in the

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half-life of $Pu^{240}$ would result in a change of ~0.15 in $\sigma_f(40)/\sigma_f(49)$.

Availibility of Pu considerably higher in $Pu^{240}$ content would of course make a more precise determination of $\sigma_f(40)/\sigma_f(49)$ by this method possible.

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