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LA REPORT 103

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June 30, 1944

This document contains 13 pages

THE RATIO OF THE FISSION CROSS SECTIONS OF 49 AND 25 FOR THERMAL NEUTRONS AND THE RATIO $[1 + \alpha(49)] / [1 + \alpha(25)]$

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Physics - Fission

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ABSTRACT

The ratio of the fission cross sections of 49 and 25 has been measured, using the highly thermalized neutrons in a graphite block, irradiated by neutrons from the Be + d reaction in the cyclotron. The ratio has been found to be 1.40 ± 0.02. By use of the energy dependence of the cross sections as found by the modulation experiments, the ratio of cross sections at energy KT (neutron velocity = 2200 m/sec) has been calculated and is 1.28. This number together with total absorption cross sections of 640 barns for 25 and 1056 barns for 49 leads to a value of $\left[1 + \alpha(49)\right]/\left[1 + \alpha(25)\right] = 1.29$.

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THE RATIO OF THE FISSION CROSS SECTIONS OF 49 AND 25 FOR THERMAL NEUTRONS AND THE RATIO $[1+\alpha(49)]/[1+\alpha(25)]$

The ratio of the fission cross sections of 49 and 25 has been measured by a comparison method, using the highly thermalized neutrons in the graphite block at the cyclotron. The value obtained is in disagreement with previous determinations,[1),2)] due to the use of more completely thermalized neutrons in this work. From this ratio, the ratio of cross sections for neutrons of velocity 2200 m/sec has been calculated. This ratio, together with the best known values for the total capture cross sections of 49 and 25, leads to a determination of the quantity $[1+\alpha(49)]/[1+\alpha(25)]$ where α is the ratio of the radiative capture cross section to the fission cross section.

EXPERIMENTAL METHOD

Six foils of 25 and four foils of 49 were used in the experiment. They were compared by counting the fissions produced in two of the foils at a time in a comparison chamber which was exposed to a thermalized neutron flux of about 2×10^5 neutrons/cm^2/sec at the center of the 11' x 7' x 6'8" graphite block at the cyclotron. The primary neutrons impinging on one face of the block were produced by the Be+d reaction. The degree of thermalization of the neutrons can be noted from the fact that covering the chamber with Cd reduced the counting rates to 0.01 percent of their former values.

The comparison chamber consisted of two parallel plate ionization

1) Chamberlain, Kennedy, Segre and Wahl, CN-469.
2) Williams, J. H., LA-25.

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chambers having a common high voltage electrode, on which the samples were placed. The three electrodes were 8.6 cm in diameter and 0.16 cm thick; the spacing between them was 1 cm. The fission particles were detected by electron collection in air at atmospheric pressure (59 cm Hg), at a field strength of 1000 volts/cm. The chamber was constructed of aluminum, except for the insulating posts, which were of 3/16" polystyrene rod.

The procedure followed in making the comparisons was to use the 25 foil E-10-H-4 as a monitor, comparing all other foils to it. In all cases several points were taken at different biases to determine the shape of the plateaus. Extrapolation of the plateaus to zero bias gave corrections of the order of 1 percent. The statistical probable errors from the fission counting were 0.5 percent or less, except for the counts on A-12-B-1, which had a probable error of 1 percent.

In order to find any systematic errors in counting, a 49 foil and a 25 foil were compared under conditions obtained by separately interchanging scalars, amplifiers, and foils, and by moving the chamber within the block. No significant change in the counting ratio was detected.

FOILS

Tables I and II give the pertinent data on the 25 and 49 foils. The diameters given refer to the deposits of active material. All the foils were deposited on 1 or 2 mil Pt. The notes in the tables describe the various methods of determining the weights. In Table I, R_w is the ratio of the weight of 28 to the weight of 25.

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RESULTS

Tables III and IV contain a summary of the comparison measurements. The two values of each the counting ratios are given, obtained from different runs taken a day or so apart. In Table III column A contains weights of the monitor computed from the weight of the sample from its α count and from the fission counting ratio obtained in this experiment; the weights in column B were computed in the same way but by using the weights of the samples given by Chamberlain. The weights determined by weighing were not used, since past experience has shown these weights to be less reliable than the others. In Table IV the ratios of cross sections in column A were obtained by using the average monitor weight of column A, Table III, and give an average ratio of 1.40. The ratios in column B were computed by using the average monitor weight of column B, Table III, and give an average ratio of 1.41. These data lead to a value of 1.40 ± 0.02 for $\sigma_f(49)/\sigma_f(25)$ for the neutrons in the graphite block.

DISCUSSION

This ratio of cross sections applies to the effective cross sections for the thermalized neutrons in the graphite block. The modulation work in this laboratory has shown that 49 and 25 differ in the energy dependence of their cross sections in the thermal region.[3),4)] Thus it is essential to calculate from the result of this experiment the ratio of cross sections at a particular energy. To do this it has been assumed that the neutrons in the

3) Anderson, Lavatelli, McDaniel, Sutton, LA-82.
4) Anderson, Lavatelli, McDaniel, Sutton, LA-91.

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block have a Maxwellian distribution[5)] with a temperature of 20° C. Then the number of fissions produced per second in a thin 25 foil is

$$N_{25} \int_0^\infty \frac{dn(v)}{dv} \sigma_f(25) v \, dv$$

where N_{25} is the number of 25 atoms in the foil, n(v) is the neutron density above the neutron velocity, v, and $\sigma_f(25)$ the fission cross section for 25. A similar expression holds for 49. The effective value of $\sigma_f(25)v$ is then

$$\frac{1}{n} \int_0^\infty \frac{dn}{dv} \sigma_f(25) v \, dv$$

where n is the neutron density. Fig. 1 shows plots of (1/n)(dn/dv), $(1/n)(dn/dv)\ \sigma_f(25)v$, and $(1/n)(dn/dv)\ \sigma_a(49)v$, assuming a Maxwellian distribution of neutrons and the values of $\sigma_f(25)v$ and $\sigma_a(49)v$ obtained by the modulation experiments, normalized to unity at KT (neutron velocity = 2200 m/sec). The total capture cross section of 49, $\sigma_a(49)$ was used in this plot since the energy dependence of $\sigma_f(49)$ has not as yet been measured. This substitution is good if α_{49} is constant in the thermal region. Some experimental evidence that α_{49} is roughly constant has been obtained by a Cd difference experiment, which showed that the 0.3 v resonance was at least

5) This assumption is possibly incorrect since the scattering cross section of carbon has large discontinuities in the thermal region. However, no more exact neutron distribution has been calculated as yet, and it is thought that for this application a Maxwellian distribution is not in error sufficiently to change the results significantly.

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partly due to the fission process.[4]

By a numerical integration of the 49 and 25 curves, one obtains

$$\frac{\sigma_f(25)_{eff}}{\sigma_f(25)_{KT}} = 0.975$$

$$\frac{\sigma_a(49)_{eff}}{\sigma_a(49)_{KT}} = 1.064$$

and thus

$$\left.\frac{\sigma_f(49)}{\sigma_f(25)}\right|_{KT} = 1.40 \times \frac{0.975}{1.064} = 1.28$$

This value should be considered tentative since more experiments on the energy dependence of $\sigma_f(25)$ and $\sigma_f(49)$ are being planned and will probably change the effective values of the cross sections.

From the ratio of fission cross sections at KT and the total absorption cross sections of 49 and 25 at the same energy, one can obtain a value of $[1 + \alpha(49)]/[1 + \alpha(25)]$ by using the relation

$$\frac{1+\alpha(49)}{1+\alpha(25)} = \frac{\sigma_a(49)}{\sigma_a(25)} \cdot \frac{\sigma_f(25)}{\sigma_f(49)}$$

Taking $\sigma_a(49) = 1056$ barns,[4] $\sigma_a(25) = 640$ barns,[6] and $\sigma_f(49)/\sigma_f(25) = 1.28$, one gets

$$\frac{1+\alpha(49)}{1+\alpha(25)} = 1.29$$

6) Fermi, CP-1389.

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Using the value of $\alpha(25) = 0.16$,[7] this gives $\alpha(49) = 0.50$.

The values of $\sigma_f(49)\sigma_f(25)\Big|_{thermal}$ found by previous experimenters when corrected to the present half-life of 49 (24,300 years) are:

Williams	- 1.62
Chamberlain et al	- 1.66

The discrepancies between these numbers and ours can be explained by the kind of neutrons used. The first measurement was made in paraffin where the Cd ratio for a 25 detector was 100; the second in a water shield with a Cd ratio of 7. This indicates the neutron energies were higher than ours since our Cd ratio was 10,000. While the effective $\sigma_f(25)v$ would not change very much for slightly higher neutron energies, the effective $\sigma_f(49)v$ would increase quite rapidly. This effect has been noticed in this laboratory where comparisons of a 49 foil and a 25 foil in paraffin and in the graphite block gave a 10 percent increase in $\sigma_f(49)/\sigma_f(25)$ in the paraffin.

In conclusion, our experiment measures $\sigma_f(49)/\sigma_f(25)$ for thermalized neutrons in a graphite block giving 1.40 ± 0.02 and indicates that on the basis of the present knowledge about the behavior of 49 and 25 in the thermal region $\sigma_f(49)/\sigma_f(25)\Big|_{KT} = 1.28$ for $T = 293^\circ$ K and $[1 + \alpha(49)]/[1 + \alpha(25)] = 1.29$.

7) Bailey, Blair and Russell, LA-90.

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TABLE I

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Sample	Diameter (cm)	Amount of 25			R_w
		(A) By weighing (mg)	(B) By α-counting (mg)	(C) By fission counting	
E-10-H-4	3.1	0.109 ± 0.001	0.106 ± 0.001 0.107 ± 0.001	0.110 ± 0.002	8.15
E-10-H-14	3.1	0.139 ± 0.001	0.138 ± 0.001 0.139 ± 0.001	0.140 ± 0.002	8.15
E-10-H-16	3.1	0.139 ± 0.001	0.138 ± 0.001 0.136 ± 0.001	0.140 ± 0.002	8.15
E-5-D	3.1	-----	------	0.760 ± 0.011	0.33
PXS-20 (recovered)	3.1	-----	------	0.686 ± 0.011	0.3
E-N-1		0.00473 ± 0.00005	0.00456 ± 0.00005 0.00460 ± 0.00004	-----	141

(A) Determined by Dr. Miller (Group C-4) by weighing the amount of oxide on the foil. The weight of 25 depends on the assumption that the material is all U_3O_8 and that R_w for E-10 is 8.15 and for the normal alloy is 141.

(B) Obtained by Dr. Miller by counting the α activity in a 2π counter. The first figures are the results of measurements taken before the comparisons were made; the second, the results obtained after the comparisons. The specific activities assumed were 6110 counts/min/mg for E-10 and 770 counts/min/mg of normal alloy.

(C) Measured by Chamberlain (Group P-5) by comparing the fission rate to that of a standard foil in a thermal neutron flux (Ra-Be+ paraffin). The standard, E-10-H-10, was calibrated by comparing by the same method with several foils of E-19 and normal alloy.

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TABLE II

Sample	Diameter	Amount of 49	
		(A) By α-counting (μg)	(B) By weighing (μg)
C-7-B-A	5.8	19.8 ± 0.2	
A-12-B-1	$<$ 1	0.897 ± 0.009	0.916 ± 0.009
C-6-B-B-1	2.5	25.3 ± 0.25 25.2 ± 0.25 25.1 ± 0.25	
C-6-B-B-2	2.5	25.3 ± 0.25 25.3 ± 0.25 25.5 ± 0.25	

(A) Counted by Dodson. The count on C-7-B-A was made before the comparisons; The count on A-12-B-1 after the comparisons. The first figures given for the last two foils were obtained by counting a smaller aliquot in a 2π chamber. The second figures come from a direct count of the foils, using a demultiplier. The third figures are a check on the second, taken after the comparisons were made. All the weights given are based on a half-life for 49 of 24,400 years.

(B) This foil was made by Wahl from an aliquot of a solution of PuO_2 which had been weighed directly before being dissolved. The weight is based on the assumption that the compound is pure PuO_2.

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TABLE III

Sample	(Counts from sample / Counts from monitor)	Weight of monitor (mg)	
		A	B
E-10-H-14	1.34, 1.33 } 1.335	0.1037	0.1048
E-10-H-16	1.305, 1.29 } 1.30	0.1054	0.1076
E-5-D	7.30, 7.35 } 7.32	----	0.1038
PXS-20	6.80, 6.65 } 6.72	----	0.1021
E-N-1	0.445, 0.445 } 0.450	0.1020	----
	Average	0.1037	0.1046

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TABLE IV

Sample	$\left(\frac{\text{Counts from sample}}{\text{Counts from monitor}}\right)$		σ_{49}/σ_{25}	
			A	B
C-7-B-A	0.253 0.249	0.251	1.338	1.348
A-12-B-1	0.0126 0.0120	0.0123	1.427	1.440
C-6-B-B-1	0.335 0.334	0.335	1.403	1.414
C-6-B-B-2	0.344 0.340	0.342	1.421	1.433
		Average	1.397	1.409

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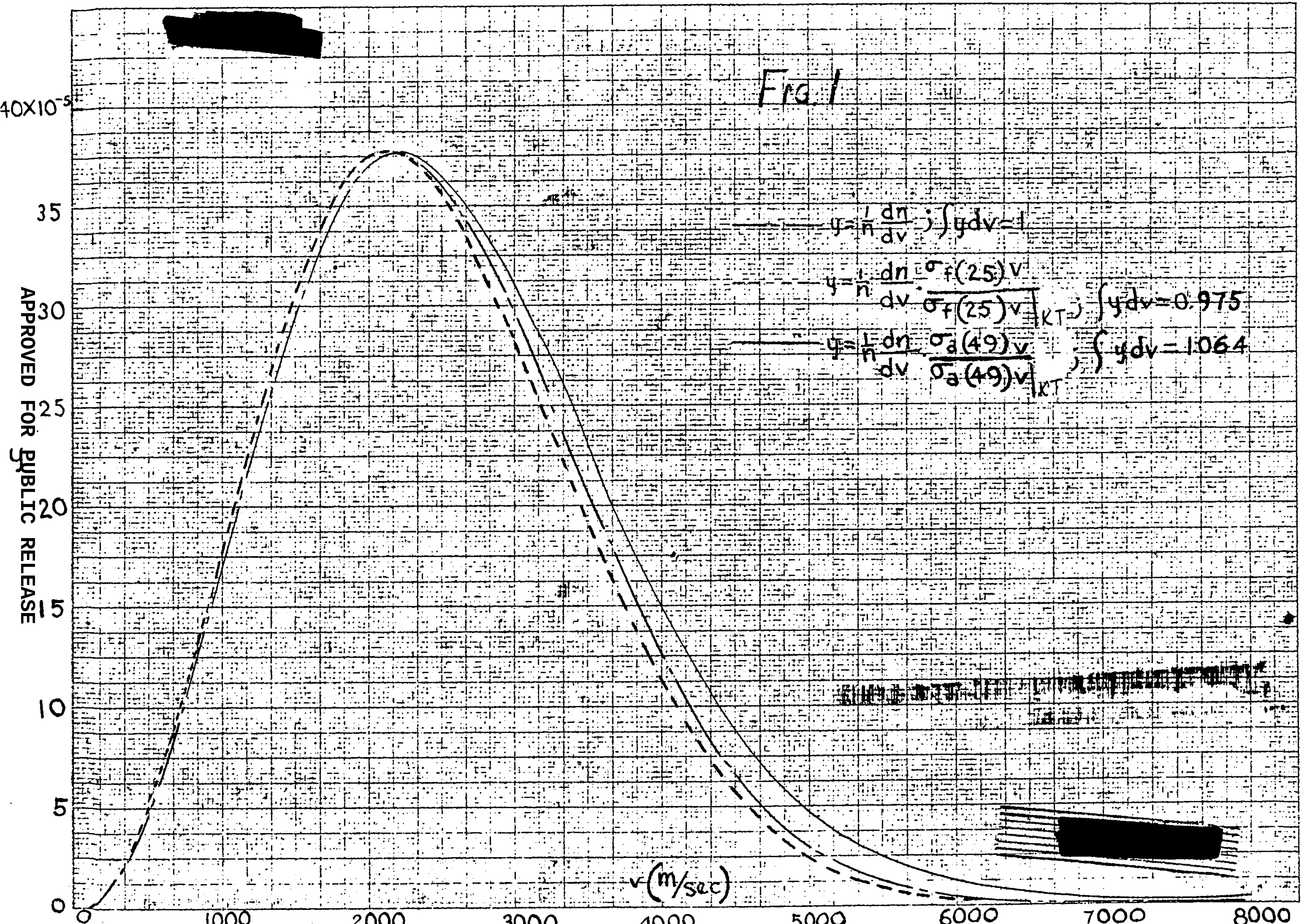

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