obtained from the one measurement here. The measurements of Sunyar[10] indicate that $B(E2)_{77}=0.10$.

The 279-kev ($5/2^+$) and the 545-kev ($7/2^+$) levels could be members of the ground-state rotational family.[4] The 77-kev ($1/2^+$) and 268-kev ($3/2^+$) levels are then supposed to be members of a second rotational family. It should be possible to excite the next rotational state ($5/2^+$, about 700 kev[11]) of this family. No indication of such a level was seen, in agreement with the expected intensity of the excitation.

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One of us (B. E.) wishes to thank the MIT Foreign Student Summer Project for making his stay at MIT possible and the Fulbright Foundation for a travel grant.

[10] A. W. Sunyar, Phys. Rev. **98**, 653 (1955).
[11] A. Kerman and B. M. Mottelson (private communication).

TABLE I. Values of B/e^2 in units of 10^{-48} cm^4 calculated by use of classical $f(\theta,\xi)$ function. The cross section used for the 268-kev excitation was calculated as 18% of the cross section for the composite (268+279)-kev line.

	Coulomb excitation of levels in Au at:			
Angle	545 kev	279 kev	268 kev	77 kev
60°	0.47	0.29		
95°	0.40	0.30		0.22
110°	0.41	0.30		
130°	0.39	0.32		
Mean	0.42	0.30	0.066	0.22
(a)	0.470	0.334	0.088	<0.20

[a] See reference 8.

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Neutron Resonance Structure of Uranium-238*

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Modifications in the Argonne fast-neutron chopper and its installation at the reactor *CP*-5 are described. With this system, neutron transmissions of very pure samples of U^{238} were measured. Parameters for the resonances observed were obtained by a refined wing shape analysis as well as by the conventional area analysis. A previously unobserved level having a smaller reduced neutron width than any heretofore reported was detected at 10.2 ev; it is interpreted as being a *p*-wave resonance. Average parameters of significance to nuclear theory are deduced. For reactor application, the resonance capture integral is calculated from the parameters and is found to be in excellent agreement with the directly measured value.

I. INTRODUCTION

A DESCRIPTION of the Argonne fast-neutron velocity selector and its use at the original heavy water moderated pile *CP*-3′, was given in a previous paper.[1] After modification of all of its major components, the velocity selector was installed at the new pile *CP*-5 in the summer of 1954. The present paper lists these modifications and presents the first data obtained with the improved system.

II. APPARATUS

The great increase in the neutron flux available from *CP*-5 as compared to *CP*-3′ (about a factor of 20) made it possible to improve almost every characteristic of the velocity selector; resolution was improved, counting rates and signal-to-background ratios were increased, a second order effect was almost eliminated, and the minimum sample size was decreased.

The most important changes were made in the chopper rotor. The second order effect, an overlapping of neutron bursts, was essentially eliminated by blocking 4 of the original 6 slits. Fast-neutron leakage through the 16-inch steel rotor was greatly diminished by replacing 3 inches of the steel by Monel metal. With these changes it was feasible to use a neutron flight path of almost 60 meters (58.7), giving a resolution of 0.08 μsec/meter.

The detector used, a boron-loaded liquid scintillator, has been described elsewhere.[2] Its important improvement, as compared with the counter of reference 1, is an enlarged area, namely 37 in.^{2}

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Now at Operations Research Office, The Johns Hopkins University, Chevy Chase, Maryland.
[1] Bollinger, Dahlberg, Palmer, and Thomas, Phys. Rev. **100**, 126 (1955).
[2] L. M. Bollinger, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 4, p. 47.

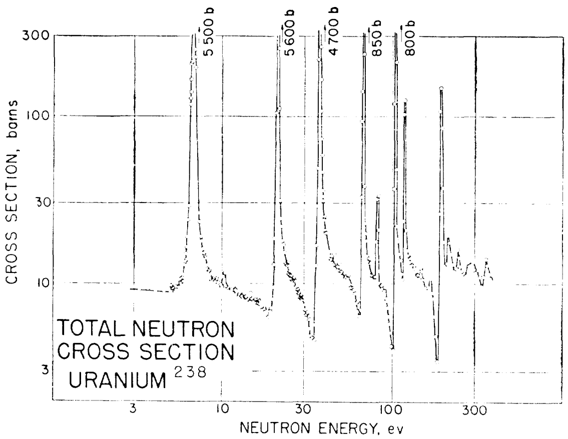

FIG. 1. Total cross section of U^{238} as a function of neutron energy. The peak cross sections indicated on the figure are measured values.

The increase in the number of time channels required to cover a given energy range for a greater neutron flight path was to some extent lessened by making the 100-channel time analyzer more flexible. Simple changes in design made it possible to split the channels into two groups which could be independently located in time.

III. RESULTS

Because of their importance in determining the characteristics of thermal nuclear reactors, the slow neutron cross sections of uranium have been intensively studied. In most of the early studies, only integral properties of the resonance structure were measured. The latest studies include a careful integral-type determination of the absorption resonance integral[3] and three measurements of the energy dependence of the total cross section[4–6] of normal uranium in which the instrumental resolution used was comparable with that employed for the present investigations. In one of these,[5] the scattering cross section was also measured.

In the present measurements, the neutron transmission of 8 samples of U^{238}, ranging in thickness from 0.001 to 0.70 inch, was studied over the energy range 5 to 300 ev. The largest known impurity in the samples was 0.04% of U^{235}, hence it is certain that all the resonances observed must be attributed to the isotope U^{238}. The full resolution available, namely 0.08 μsec/meter, was used for all resonances at energies greater than 20 ev; for the 6.7-ev resonance, the chopper was operated at a reduced speed, giving a resolution of 0.095 μsec/meter.

A general view of the resonance structure of U^{238} is given in Fig. 1, where parts of all the runs taken were used in making a plot of total cross section *vs* neutron energy. Two striking qualitative features of the data, an apparent tendency toward a uniformity of level spacings and strongly asymmetric resonance shapes, combine to produce a cross-section behavior of unusual interest.

In obtaining quantitative information about the resonance structure, the transmission dips observed were assumed to be due to *s*-wave resonances for which the radiative capture and scattering cross sections σ_γ and σ_s are given by[7]

$$\sigma_\gamma=\sigma_0\frac{\Gamma_\gamma}{\Gamma}\left(\frac{E_0}{E}\right)^{\frac{1}{2}}(1+x^2)^{-1}, \tag{1}$$

$$\sigma_s=4\pi R^2+\sigma_0\frac{\Gamma_n}{\Gamma}\left[1+\left(2\frac{R\Gamma}{\lambda\!\!\!^{-}_0\Gamma_n}\right)x\right](1+x^2)^{-1}, \tag{2}$$

where

$$\begin{aligned}\Gamma&=\Gamma_\gamma+\Gamma_n,\\ x&=(2/\Gamma)(E-E_0),\\ \sigma_0&=4\pi\lambda\!\!\!^{-}_0{}^2 g(\Gamma_n/\Gamma).\end{aligned} \tag{3}$$

Here E is the kinetic energy of the neutron, the constants E_0 and $2\pi\lambda\!\!\!^{-}_0$ are the neutron energy and wavelength at resonance, R is the nuclear radius, Γ, Γ_n, and Γ_γ are the total, neutron, and radiation widths, and σ_0 is the cross section at resonance. The statistical factor g is unity for U^{238}. The above relationships are expected to be valid only for stationary target nuclei, and the effect of thermal motion of these nuclei must be taken into account by integrating over their velocity distribution.

Uranium is a more favorable case for study than are many nuclei because resonance parameters may be deduced both from the areas above transmission dips and by curve fitting. For the resonances at 6.7, 21.8, 36.6, and 66.0 ev, all parameters were obtained by a straightforward application of the standard transmission area method.[8,9] This method gives, in essence, a value of $\sigma_0\Gamma^p$ for each transmission area, with the constant p depending on $n\sigma_0$, where n is the sample thickness in atoms per cm^2. For $n\sigma_0\ll1$, p approaches 1 and for $n\sigma_0\gg1$, it approaches 2; hence the independent parameters σ_0 and Γ may be obtained from a measurement of transmission areas for two samples having appropriate values of $n\sigma_0$. For resonances at energies greater than 75 ev it was felt that greater accuracy was obtained by deducing parameters with an assumed value of the radiation width Γ_γ, the value used being a weighted mean of the values that were obtained for the

[3] R. L. Macklin and H. S. Pomerance, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 5, p. 96.

[4] Harvey, Hughes, Carter, and Pilcher, Phys. Rev. **99**, 10 (1955).

[5] J. E. Lynn and N. J. Pattenden, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 4, p. 210.

[6] Fluharty, Simpson, and Simpson, Phys. Rev. **103**, 1778 (1956).

[7] H. A. Bethe, Revs. Modern Phys. **9**, 115 (1937).

[8] Melkonian, Havens, and Rainwater, Phys. Rev. **92**, 702 (1953).

[9] Seidl, Hughes, Palevsky, Levin, Kato, and Sjöstrand, Phys. Rev. **95**, 476 (1954).

first four resonances. A more detailed discussion of this technique is given by Palmer and Bollinger.[10]

The strong asymmetry observed for the shape of most of the uranium resonances provides the second approach for deducing parameters. For such cases, a convenient technique for curve fitting the wings of a resonance, where the effects of resolution and Doppler broadening are negligible, has been used[1,11,12] in several experiments to obtain values of $\sigma_0\Gamma(R/\lambda_0)$. If one uses the single-level formulas, Eqs. (1) through (3), the technique is readily understood by observing that in the neighborhood of a particular resonance at E_0, having parameters σ_0, Γ, etc., yet far enough away that $x\gg1$, the total cross section σ_t may be written in the form

$$\sigma_t-\frac{1}{4}\left[\frac{\Gamma_\gamma}{\Gamma}\left(\frac{E_0}{E}\right)^{\frac{1}{2}}+\frac{\Gamma_n}{\Gamma}\right]\frac{\sigma_0\Gamma^2}{(E-E_0)^2}-\sum_r\sigma_r$$
$$=\sigma_0\Gamma\frac{R}{\lambda_0}\frac{1}{(E-E_0)}+4\pi R^2. \quad (4)$$

The sum over r is a correction for the effect of neighboring resonances r for which parameters are known. A plot of the left-hand side against $(E-E_0)^{-1}$ should give a straight line having a slope of $\sigma_0\Gamma(R/\lambda_0)$ and an intercept of $4\pi R^2$. For advantageous cases, such as the resonances in uranium, the second and third terms on the left of Eq. (4) are small compared to the first term on the right; hence, the use of approximate values for the constants in these terms does not lead to serious inaccuracy in the constants on the right.

There are two drawbacks to the above technique, as previously used, for deducing resonance parameters. First, in obtaining Eq. (4) no account was taken of the effect of interference between resonances. Second, because of large uncertainties[12] in the absolute value of the measured intercept $4\pi R^2$, the value of R used in getting $\sigma_0\Gamma$ from the observed slope was calculated from the $A^{\frac{1}{3}}$ relationship, a procedure which can introduce a large error in the derived value of $\sigma_0\Gamma$. Errors of this kind are unnecessary for the present data, however. Using the familiar multi-level scattering cross-section relationship,[13] with $g=1$, it is easily shown[14] that, in the

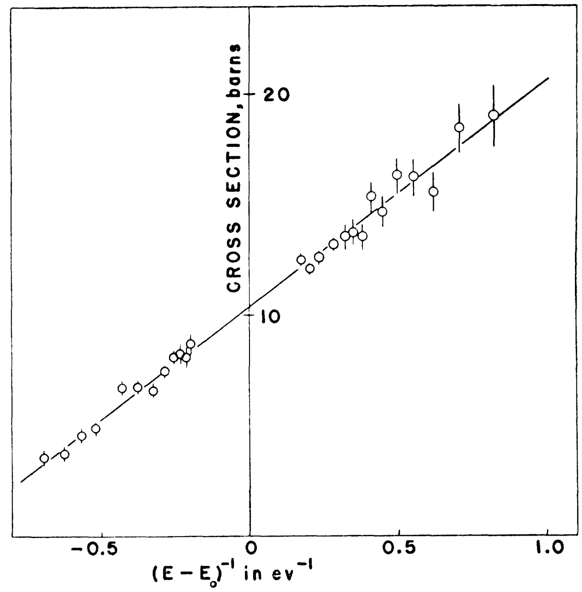

FIG. 2. Illustration of the method of wing shape analysis for the resonance at 20.8 ev. The ordinate is $\sigma_t-\frac{1}{4}\sigma_0\Gamma^2(E-E_0)^{-2}-\sum_r\sigma_r$, it being assumed that over the range of interest $[(\Gamma_\gamma/\Gamma)(E_0/E)^{\frac{1}{2}}+(\Gamma_n/\Gamma)]=1$. The resonances r for which corrections are made are those at 6.7 and 36.6 ev. The intercept on the ordinate gives $4\pi R_0^2=10.4$ barns and the correction for the scattering component of neighboring resonances was 1.5 barns at 20.8 ev. Thus the effective radius R_e used in deducing $\sigma_0\Gamma$ from the slope is given by $4\pi R_e^2=8.9$ barns. This value of R_e differs from R_0 by about 7%. The relationship between R_e and R_0 is explained in reference 14.

wings of a resonance, the cross-section relationship, including the effect of interference between resonances, can be written in the form of Eq. (4), the only difference being that the two R's appearing in (4) are not now equal. Let the constant term, the intercept of the cross-section axis, be $4\pi R_0^2$. Then the effective radius R_e which appears in the $(E-E_0)^{-1}$ term is given by

$$4\pi R_e^2=4\pi R_0^2+\sum_r\left[\left(\frac{\Gamma_n}{\Gamma}\sigma\right)_r\right]_{E=E_0}, \quad (5)$$

[10] R. R. Palmer and L. M. Bollinger, Phys. Rev. **102**, 228 (1956).
[11] Kato, Hughes, and Levin, Phys. Rev. **93**, 931 (1954).
[12] J. S. Levin and D. J. Hughes, Phys. Rev. **101**, 1328 (1956).
[13] Reference 7, Eq. (425).
[14] Expanding Bethe's multi-level relationship for the case $g=1$ and $x\gg1$, one may reduce the expression for the scattering cross section to the form

$$\sigma_s=\frac{1}{4}\frac{\Gamma_n}{\Gamma}\frac{\sigma_0\Gamma^2}{(E-E_0)^2}+\frac{\sigma_0\Gamma}{\lambda_0}\left\{R+\frac{1}{2}\sum_q\frac{\Gamma_{nq}\lambda_q}{E-E_q}\right\}\frac{1}{E-E_0}+4\pi\left\{R+\frac{1}{2}\sum_q\frac{\Gamma_{nq}\lambda_q}{E-E_q}\right\}^2,$$

where the subscript 0 refers to the nearest level and q refers to all other levels. For widely spaced levels, the range in E over which data are useful for curve fitting is small compared to E_0-E_q. Thus to a first approximation the bracketed quantity $\{R+\frac{1}{2}\sum_q\Gamma_{nq}\lambda_q(E-E_q)^{-1}\}$ is a constant, say R_e. In an application of the method to the uranium data, the variation in R_e is unimportant for the $(E-E_0)^{-1}$ term but it should be reduced in the $4\pi R_e^2$ term. Let the resonances which are primarily responsible for variations in R_e be labeled with a subscript r. Then

$$4\pi R_e^2=4\pi\left\{\left(R+\frac{1}{2}\sum_i\frac{\Gamma_{ni}\lambda_i}{E-E_i}\right)^2+\sum_r\frac{\Gamma_{nr}\lambda_r}{E-E_r}\left(R+\frac{1}{2}\sum_i\frac{\Gamma_{ni}\lambda_i}{E-E_i}\right)+\frac{1}{4}\left(\sum_r\frac{\Gamma_{nr}\lambda_r}{E-E_r}\right)^2\right\},$$

where $0\neq i\neq r$. For the present data the last term in the above equation is small compared to the other two terms and no significant error is made by moving the squaring operation inside the summation sign, thus neglecting cross terms. Having made this approximation, $4\pi R_e^2$ becomes the sum of two parts, one being essentially a constant $4\pi R_0^2$, and the other the scattering component of the single level contributions of the resonances r. Further, after adding the capture component, the total cross section may be written in the form of Eq. (4) with the constant term being $4\pi R_0^2$ and the radius appearing in the $(E-E_0)^{-1}$ term being R_e. The appropriate value of R_e to be used is that evaluated at E_0, which is related to the constant R_0 by Eq. (5).

TABLE I. Parameters of neutron resonances in U^{238}. The errors given are standard statistical errors.

E_0 (ev)	σ_0 (barns)	Γ (mv)	Γ_γ (mv)	Γ_n (mv)	$\Gamma_n^0\times10^3$ ($ev^{\frac{1}{2}}$)	$\frac{1}{2}\pi\sigma_0\Gamma_\gamma/E_0$ (barns)
6.67	20 500±3700	27.5± 2.8	26.0± 3.0	1.45± 0.12	0.56	125 ±12
10.2	15	24	24[a]	1.4 ×10⁻³	4.4×10⁻⁴	0.1
20.8	39 000±3300	31.8± 1.9	21.9± 2.3	9.9 ± 0.4	2.16	64.5± 4
36.6	38 000±7000	63 ± 8	29 ±10	34 ± 2.3	5.6	44.6±13
66.0	19 000±4000	49 ± 7	25.6± 9	23.4 ± 1.5	2.8	12.2± 3.4
80.5	2650± 320	26 ± 2	24[a]	2.1 ± 0.2	0.23	1.2± 0.1
89	...	...	...	...	...	...
102	19 200± 700	98 ± 5	24[a]	74 ± 5	7.3	7.1± 1.2
117	11 400±1000	50 ± 4	24[a]	26 ± 4	2.4	3.7± 0.9
146	570± 200	25 ± 2	24[a]	0.78± 0.27	0.064	0.1
165	1800± 550	27 ± 2	24[a]	3.1 ± 1.1	0.24	0.4
189	11 600± 250	166 ±14	24[a]	142 ±14	10.3	2.3
210	7600± 800	62 ± 9	24[a]	39 ± 9	2.7	1.4
237	6300± 800	56 ±10	24[a]	32 ±11	2.1	1.0

[a] Assumed values of $\Gamma_\gamma=(24\pm2)$ mv was used for these levels.

where the sum is over the same resonances r that were considered in Eq. (4). The accuracy of the approximation (5) depends on the degree to which $|E_r-E_0|$ is large compared to $|E-E_0|$. It is clear, from its definition, that R_e will vary from level to level.

The cross sections in off-resonance regions in the present measurements are thought to be accurate, with regard to systematic errors, to about one percent, an accuracy which makes the above refinement in approach worthwhile. An application of the method to the 20.8-ev resonance in uranium is illustrated in Fig. 2.

The parameters obtained by combining the results from both area and wing analyses are given in Table I. In all cases where parameters are obtained in both ways, the agreement between the results is exceedingly good, as is shown in Table II, where values of $\sigma_0\Gamma$ are compared; the agreement would have been generally poorer had R_0, rather than R_e, been used in obtaining $\sigma_0\Gamma$ from the wing curve fit. In the case of the 6.67-ev resonance, values of $\sigma_0\Gamma^2$ can also be obtained in both ways, namely 15.7±0.7 and 14.9±1.0 b-ev^2 by area and wing analyses, respectively.

Values of R_0, as defined above, are also given in Table II. For each of the resonances listed, corrections were made for the effect of two neighboring levels, one at lower and one at higher energy, except for the 6.67-ev resonance, for which the properties of the lower neighbor at negative energies were unknown; the effects of the 10.2-, 80.5-ev, and 89-ev levels were not included in these corrections. Because of the way in which it was determined, $4\pi R_0^2$ is a measure of the potential scattering in an energy region from which the effects of nearby levels have been removed. It should have a strong tendency to be, therefore, an average property of the nucleus, insensitive to the effects of particular resonances. The excellent agreement between the four values of R_0 obtained gives us confidence in the accuracy of the measurements and suggests that 9.1×10^{-13} cm is a reliable value of the nuclear radius. This result is in satisfactory agreement with the value of 9.3×10^{-13} cm obtained by Hughes and Pilcher,[15] using an entirely different technique. The relation $R=1.45\times10^{-13}\,A^{\frac{1}{3}}$ cm gives 9.0×10^{-13} cm.

The parameters of Table I are generally in satisfactory agreement with those obtained at Brookhaven,[4] Harwell,[5] and MTR.[6] The major pont of disagreement is that in the present measurements several small resonances were detected which were not observed in other studies. The smallest of these, that at 10.2 ev, was not detected in any of the other measurements; it is discussed in detail in the following paragraphs. A second small resonance, that at 89 ev, was reported in reference 4 but not in reference 5 or 6. The present measurements give parameters for this level that have large uncertainties, but its existence is confirmed.‡

A sensitive test of the quality of the agreement between the several studies of the resonance parameters of U^{238} is provided by a comparison of the values obtained for radiation widths Γ_γ; such a comparison is made in Table III. It is seen that essentially all the measured values are consistent with a unique value of Γ_γ in the range from 0.023 to 0.027 ev. The close similarity of these four sets of data, which were obtained independently using quite different techniques, is one of the best demonstrations yet given of the reliability of the area method of analysis and of its application.

The parameters deduced for most of the resonances of Table I follow a pattern that is consistent with the results obtained for many other nuclei. The reduced neutron width for the 10.2-ev resonance is the smallest yet reported for any nuclide, however, and suggests a need for a closer examination. Careful tests were made to establish that the observed transmission dip was not caused by an impurity in the sample. In the very pure

[15] D. J. Hughes and V. E. Pilcher, Bull. Am. Phys. Soc. Ser. II, 1, 188 (1956).

‡ *Note added in proof.*—In an exploratory run made with a new chopper having a much improved resolution (~0.04 μsec/m), the 89-ev resonance was observed with great clarity. From the area of the transmission dip obtained, the neutron width Γ_n is found to be 0.084±0.014 mv for an assumed Γ_γ of 24±2 mv.

TABLE II. Comparison of results given by area and wing analyses. Standard statistical errors are used.

E_0 (ev)	Area (ev $-b$)	Wing (ev $-b$)	R_0 (cm)
6.67	574± 50	540± 50	9.1×10^{-13}
20.8	1217± 60	1240± 48	9.1×10^{-13}
36.6	2280±100	2120±165	9.1×10^{-13}
66.0		930±120	9.3×10^{-13}

U^{238} sample of 0.70-inch thickness, there were no known impurities large enough to explain the effect. Moreover, a search of the literature showed that only tantalum has a prominent resonance at approximately 10.2 ev; consecutive runs with the uranium and a thin tantalum sample showed that the flight time for the tantalum resonance was 6 μsec longer than that in uranium, a time difference too large to be explained by instrumental instability. As a second check on the possibility of an unknown impurity, a sample of exceptionally pure normal uranium was also studied. The transmission dip observed for this sample yields resonance parameters that are consistent with those from the U^{238} sample.

The evidence presented above convinces us that the transmission dip observed at 10.2 ev is caused by U^{238}. If one assumes it to be an s-wave resonance, the reduced neutron width is found to be 6000 times smaller than the average reduced width. For a p-wave resonance, on the other hand, the centrifugal barrier factor is 24 000 at 10.2 ev; thus the transmission dip observed is typical of that which would be expected for a p-wave resonance. It seems, then, that the probability is greater for the 10.2-ev level to be a p-wave rather than an s-wave resonance.

From the list of parameters given in Table I we may deduce several averages that are of interest to nuclear theory, namely $\bar{\Gamma}_\gamma$, $\bar{\Gamma}_n^0$, $\bar{D}$, and $\bar{\Gamma}_n^0/\bar{D}$, where Γ_n^0 is the reduced width and D is the level spacing per spin state. In calculating these averages, the parameters for the level at 10.2 ev are not included because it seems probable, as shown above, that it is a p-wave resonance.

All the values of Γ_γ measured are consistent with the assumption that Γ_γ is the same for all resonances. Under this assumption, we obtain a weighted average value of 0.0238±0.0016 ev for $\bar{\Gamma}_\gamma$.

It is believed that the probability is high that all resonances below 189 ev were detected. Over this range,

TABLE III. Comparison of measured values of Γ_γ. The errors listed, which are those given in the original publications, do not indicate the relative accuracies of the results because they do not have the same meaning for all sets of measurements. The errors quoted are as follows: ANL—standard statistical errors; BNL—no statement of nature of errors given, but they are believed to be probable errors, i.e., 0.675 times the standard error; Harwell—no clear statement of nature of errors given; MTR—estimates of limits of error.

E_0 (ev)	ANL	BNL[a]	Harwell[b]	MTR[c]
6.67	26.0± 3.0	24± 2	26.1±1.5	
20.8	21.9± 2.3	25± 5	28.8±2.3	25.9±12
36.6	29 ±10	29± 9	24.9±4.2	27.7±24
66.0	25.6± 9	17±10	18.6±2.7	39.1±26
80.5				
102			15.5±5.4	24.0±26
117			13.6±4.8	24.0±26

[a] See reference 4.
[b] See reference 5.
[c] See reference 6.

then, $\bar{D}=18\pm4$ ev. For the ratio $\bar{\Gamma}_n^0/\bar{D}$, we include the wider energy range 0 to 255, since a failure to see small resonances will have a negligible influence on the ratio. The result obtained is $\bar{\Gamma}_n^0/\bar{D}=(1.43\pm0.4)\times10^{-4}$ ev$^{-\frac{1}{2}}$. The above values for $\bar{\Gamma}_n^0/\bar{D}$ and $\bar{D}$ give $\bar{\Gamma}_n^0=(2.6\pm0.5)\times10^{-3}$ ev$^{\frac{1}{2}}$. For these three averages the errors quoted are probable errors calculated on the basis of the number of levels used, if one assumes an exponential density distribution for both Γ_n^0 and D.

In addition to average quantities of interest to nuclear theory, the data of Table I allow us to calculate integral quantities of importance for reactor design. Of particular interest is the capture resonance integral Σ_γ defined by

$$\Sigma_\gamma=\int_{E_1}^{E_2}\sigma_\gamma\frac{dE}{E}=\frac{\pi}{2}\sum_r\left(\frac{\sigma_0\Gamma_\gamma}{E_0}\right)_r+K\int_{-E_1}^{+E_2}\frac{dE}{E^{\frac{3}{2}}}. \quad (6)$$

The integral on the right is the contribution by the $1/v$ portion of the cross section. The exact values of the limits E_1 and E_2 are unimportant; let them be 0.4 ev and 2 Mev. The main part of Σ_γ is caused by the levels for which parameters are given in Table I; they give a contribution of 264±19 barns. In addition, approximate calculations give a value of 14 barns for the effect of resonances above 260 ev and 1.2 barns for the $1/v$ contribution. The capture resonance integral deduced from the present data is, therefore, 279±20 barns. The excellent agreement between this value and a recent integral measurement[3] of 282 barns is most gratifying.