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FAST-NEUTRON CROSS SECTIONS OF HAFNIUM, GADOLINIUM, AND SAMARIUM

by

G. L. Sherwood, A. B. Smith,
and J. F. Whalen

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Reactor Physics Division

May 1969

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FAST-NEUTRON CROSS SECTIONS OF HAFNIUM, GADOLINIUM, AND SAMARIUM*

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ABSTRACT

Elastic and inelastic neutron-scattering cross sections of elemental hafnium, gadolinium, and samarium were measured at incident neutron energies of 0.3-1.5 MeV. The experimental resolution was sufficient to reasonably resolve elastic and inelastic processes and to define individual inelastic cross sections for the most appreciably excited states. The total neutron cross sections were determined up to 1.5 MeV with resolutions of $\gtrsim$2.5 keV. Within the precisions of the measurements, all observed cross sections were relatively smooth functions of energy. The experimental results were compared with those obtained from calculations based upon both spherical and deformed optical potentials and statistical theory, inclusive of fluctuation corrections. The calculated results were descriptive of measured total, elastic scattering, and, to a lesser extent, inelastic scattering cross sections. Experimental and calculated results were compared with previously reported measured values and with the contents of several evaluated neutron data sets used in reactor design.

I. INTRODUCTION

The elements hafnium, gadolinium, and samarium are complex mixtures of even and odd isotopes. Some of the isotopes are fission products, and some have large thermal-capture cross sections. As a result, they are found in reactor systems and are often used as reactor poisons or control components. The isotopes of these elements are deformed, and their low-lying excited states are predominantly rotational and vibrational structures.[1,2] Even at relatively low incident neutron energies, these collective states can be directly excited by inelastic neutron-scattering processes. The strength of these direct reactions (DR's) increases with incident energy and leads to inelastic neutron distributions differing signnificantly from those associated with compound nucleus (CN) processes.

---

*All numerical data contained here have been transmitted to the National Neutron Cross Section Center (NNCSC), Brookhaven National Laboratory.

Despite the applied importance and physical interest of hafnium, gadolinium, and samarium, relatively little is known of the interaction of fast neutrons with these elements. Studies of low-energy cross sections have provided values of the $\ell = 0$ strength function, but not always with good agreement between experiments or with calculation.[3] At neutron energies above ~100 keV, measured total cross sections are not consistent, particularly with respect to the presence of intermediate structure.[4-6] Elastic neutron-scattering cross sections have been reported at selected incident energies, primarily near 1.0 MeV.[7,8] Often the experimental resolutions previously used did not clearly differentiate the elastic scattering from inelastic processes. Studies of inelastic neutron scattering from these elements have been largely confined to indirect observation of the $(n,n'\gamma)$ processes[9] and to determinations of nonelastic scattering cross sections.[10]

The excited structure of a number of the isotopes of hafnium, gadolinium, and samarium has been extensively studied through coulomb excitation, charge particle, and neutron-capture gamma-ray measurements.[2,11] In some cases, a reasonably detailed knowledge of the excited structure has resulted, particularly for the odd isotopes. However, general understanding of the structure is incomplete, and, coupled with uncertainties in reaction mechanisms and associated potentials, this makes the quantitative calculation of neutron cross sections difficult.

The objective of the present work is to provide fast-neutron cross sections of hafnium, gadolinium, and samarium for applied use in reactor design; to provide the experimental basis for developing reaction models of wide and quantitative usefulness; and to further the understanding of the structure of deformed nuclei.

II. EXPERIMENTAL METHODS

The fast-neutron time-of-flight method was used to determine scattered neutron-velocity distributions. Total neutron cross sections were derived from monoenergetic neutron transmissions. These techniques and associated apparatus have been described elsewhere and will not be detailed here.[12,13] The time-of-flight method employed concurrently-determined scattered neutron-velocity distributions at eight scattering angles distributed over the interval 25-155°. The scattering angles varied during the studies, but were carefully determined for a given measurement. Throughout the work, the $^{7}Li(p,n)^{7}Be$ reaction was used as a neutron source in such a manner as to provide the desired incident neutron spreads at the sample under study.[14] All scattering samples were metallic right cylinders 2.0 cm high and 2.0 cm in diameter fabricated from the natural element. Their chemical purities were >98% per atom, and the sample densities those of the natural element. Neutrons were incident upon the base of the cylinders in the total cross-section measurements and upon the lateral cylindrical surfaces in the scattering studies. All scattering cross sections were determined relative to the differential elastic scattering cross sections of carbon.[15] Using a Monte Carlo procedure,[13] we corrected the scattering measurements for incident beam attenuation, for finite angular resolution of the apparatus, and for multiple scattering effects. All measured results were reduced to barns per atom of the natural element.

III. EXPERIMENTAL RESULTS

A. Total Neutron Cross Sections

The total neutron cross sections of hafnium, gadolinium, and samarium were measured from ~0.10 to 1.5 MeV. Incident neutron-energy resolutions were 2-3 keV, and measurements were made at energy intervals of $\lesssim$5 keV. The statistical errors associated with the measured data points were ~1%. "In-scattering" corrections were estimated, found to be small, and neglected. Figures 1-3 summarize the experimental results for hafnium,

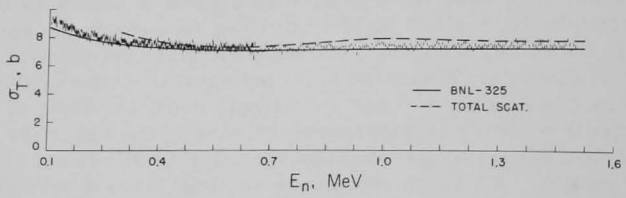

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Fig. 1. Measured Total Neutron Cross Sections of Hafnium. The vertical bars indicate measured values and their uncertainties. The dashed line denotes the sum of measured elastic and inelastic scattering cross sections. The solid curve is the "eye guide" of BNL-325.[4]

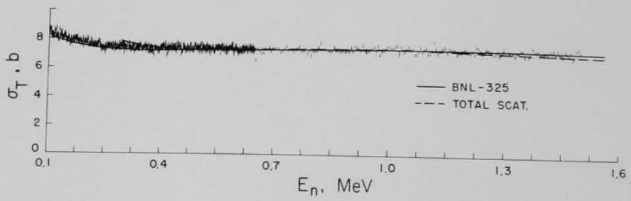

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Fig. 2. Measured Total Neutron Cross Sections of Gadolinium. Format and notation are identical to those of Fig. 1.

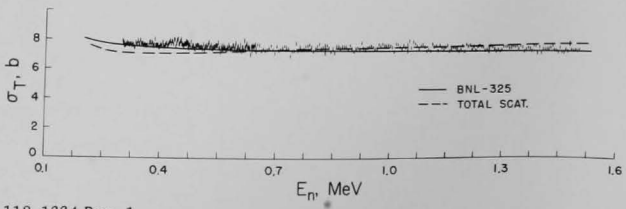

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Fig. 3. Measured Total Neutron Cross Sections of Samarium. Format and notation are identical to those of Fig. 1.

gadolinium and samarium, respectively. Numerical values are given in the appendix. The present hafnium results are in good agreement with those obtained in a number of earlier measurements,[4] but significantly higher than some of the recent values reported in Ref. 4. The present gadolinium values are in good agreement with those reported by Stupegia et al.[4] and by Gilboy and Towle.[8] However, they tend to be somewhat larger than the results of Seth[5] and do not show the reported strong intermediate structure. The possible presence of such structure is discussed in Section IV.A of this report. Generally, the total cross sections of samarium obtained in the present work are similar to previously reported values obtained with less detailed energy resolution.[4]

B. Elastic Neutron Scattering

Elastic neutron scattering was measured at incident neutron-energy intervals of $\lesssim$50 keV from 0.3 to 1.5 MeV. The incident neutron-energy spreads were ~20 keV, the scattered neutron-energy resolution ~1.5 nsec/m, and the scattered neutron sensitivity a few millibarns per steradian. The scattered-neutron resolution was usually sufficient to resolve the elastic neutron group from inelastic contributions, as is illustrated in Fig. 4. However, at incident neutron energies >1.2 MeV, the resolution was less than definitive, particularly at forward scattering angles, and the observed elastic scattering was corrected for contributions from inelastic processes associated with small reaction Q values ($|Q| \leq 100$ keV). These corrections were based upon selected good-resolution measurements and theoretical extrapolation from measured values.

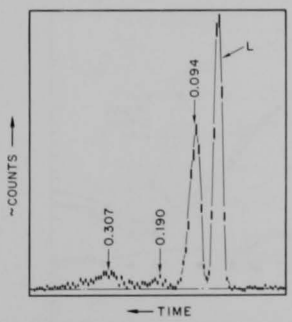

Fig. 4

Time-of-flight Distribution Obtained by Scattering 0.8-MeV Neutrons from Hafnium through an Angle of 115°. A small background has been subtracted. Vertical bars indicate statistical counting uncertainties. Neutrons due to elastic scattering and the observed inelastic excitation of states at 0.094 and 0.307 MeV are indicated. Neutrons corresponding to the excitation of a state at 0.190 MeV are attributed to double inelastic scattering to the 0.094-MeV state.

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The differential elastic scattering angular distributions were usually determined at eight scattering angles. These angles were similar, but not always identical, at various incident neutron energies. Typical values of these laboratory scattering angles were 28.5, 38.5, 53.5, 69.5, 84.5, 114.3, 129.5, 154.2°. The angular resolution of the measurements was $\lesssim$5°, largely determined by the source-sample configuration. All measured elastic scattering angular distributions were reduced to corrected cross sections

(relative to the carbon standard) and expressed as an expansion of Legendre polynomials of the form

$$\frac{d\sigma}{dn} = \frac{\sigma}{4\pi}\left[1 + \sum_{i=1}^{n} \omega_i P_i(\theta)\right], \tag{1}$$

where the scattering angle is given in the laboratory system. The parameters σ and ω_i were derived from a least-squares fit of Eq. 1 to the actual experimental values. The value n was chosen so that the fitting error on the nth coefficient did not generally exceed its value. This led to values of n = 5 at higher energies (~0.8-1.5 MeV) and n = 4 at energies of $\lesssim$0.8 MeV. The experimental results expressed in the form of the above expansion were descriptive of the individual differential measurements as indicated by the solid curves and data points of Figs. 5-8. The use of this expansion permitted easy comparison of results obtained at slightly differing scattering angles and incident neutron energies. However, extrapolation of the measured results by means of Eq. 1 beyond the experimental angular interval of ~25 to ~155° may not necessarily be valid.

The measured differential elastic scattering cross sections of hafnium, gadolinium, and samarium, expressed in the form of Eq. 1, are summarized in Figs. 9-11 and expressed in tabular form in the appendix. These results are composites of a number of measurements made over several years. Where multiple values were available within an energy increment approximating the incident-energy resolution, they were averaged to obtain

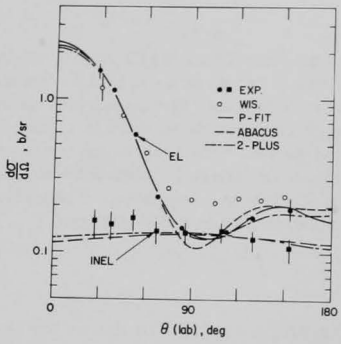

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Fig. 5. Scattering of 1.0-MeV Neutrons from Hafnium. Solid data points are the present elastic and inelastic (Q = -98 keV) results. Open points are from Ref. 7. Curves are the result of calculation as discussed in the text.

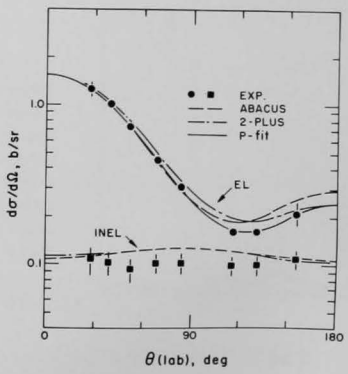

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Fig. 6. Scattering of 0.5-MeV Neutrons from Gadolinium. Elastic and inelastic (Q = -80 keV) results are indicated. The curves are discussed in the text.

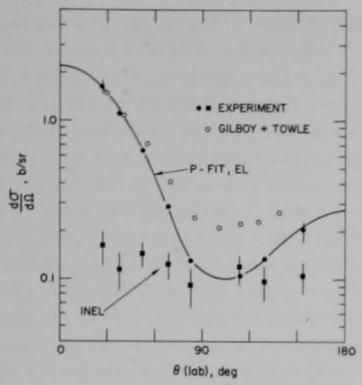

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Fig. 7. Scattering of 0.98-MeV Neutrons from Gadolinium. Solid data points are the results of the present elastic and inelastic (Q = -80 keV) measurements. Open points are from Ref. 8.

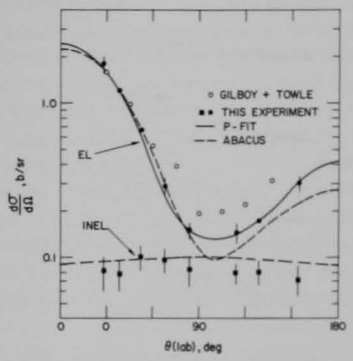

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Fig. 8. Scattering of 0.98-MeV Neutrons from Samarium. Results of present elastic and inelastic (Q = -100 keV) measurements are indicated by solid data points. Open circles indicate the values of Ref. 8. The curves are discussed in the text.

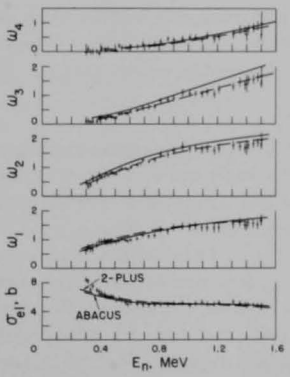

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Fig. 9. Differential Elastic Scattering Cross Sections of Hafnium, Expressed in the Form of Eq. 1. The curves indicate the results of model calculations described in the text.

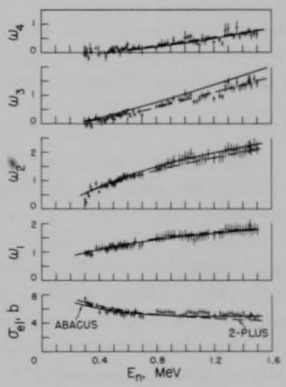

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Fig. 10. Differential Elastic Scattering Cross Sections of Gadolinium, Expressed in the Form of Eq. 1. The curves are discussed in the text.

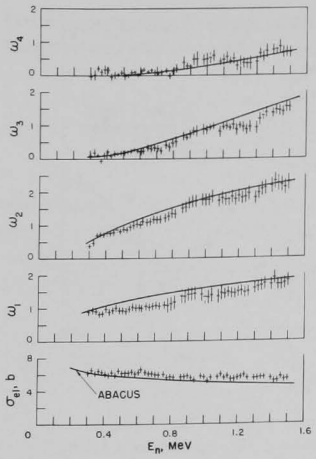

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Fig. 11. Differential Elastic Scattering Cross Sections of Samarium. The format is the same as that of Fig. 9.

the results shown. The uncertainties associated with individual differential cross-section determinations must be subjectively estimated, as they are complex functions of statistical effects, systematic uncertainties, and instrumental properties and are not necessarily constant from energy to energy or from measurement to measurement. Figures 5-8 indicate conservative estimates of these uncertainties. The influence of multiple scattering and other correction factors was generally small (10% in the worst configurations) and led to uncertainties in the measured values of only a few percent. It was judged that the integrated elastic cross section derived from Eq. 1 was known to ±8% inclusive of uncertainties in the carbon standard cross sections. This error was somewhat larger at incident energies above 1.2 MeV, because of the correction for partially resolved inelastic scattering contributions. The quoted errors associated with the ω_i values are representative of the "goodness" of the fit of Eq. 1 to the measured values and do not necessarily reflect the uncertainties in the individual points. Generally, the fit to the individual experimental points was well within the estimated experimental uncertainty. (See Figs. 5-8.)

The results of the present elastic scattering measurements are in reasonable agreement with previously reported elastic scattering angular distributions when cognizance is taken of the various experimental resolutions employed. The results of Gilboy and Towle[8] obtained by scattering 0.98-MeV neutrons from gadolinium and from samarium compare well with the sum of the elastic and first inelastic group cross sections determined in the present work. (See Figs. 7 and 8.) When corrected for inelastic content, the results obtained by Walt and Barschall[7] for the scattering of 1.0-MeV neutrons from hafnium are reasonably consistent with the results obtained in the present work, though there appears to be some discrepancy at very forward and back scattering angles. (See Fig. 5.) These differences are not outside of the experimental uncertainties.

C. Inelastic Neutron Scattering

The elements hafnium, gadolinium, and samarium each consist of five or more isotopes, of which at least 30% are of odd A.[2] All are deformed and, particularly the odd isotopes, are characterized by complex low-lying excited structure. If only isotopes of greater than 10% abundance are

considered, the number of states per element below an excitation energy of ~1.0 MeV exceeds 40. This estimate is conservative, since the structure of many isotopes is only partially known. Thus the average spacing between states barely exceeded the optimum scattered-neutron resolution of the present experiments, and it was difficult to associate an observed neutron group with the excitation of a specific nuclear state. More correctly, a neutron-emission cross section was determined. This was associated with an average reaction Q ± dQ value, assuming inelastic neutron scattering processes were the contributing factors. The Q values were determined from measured neutron flight times and flight paths and were verified by comparison with the inelastic excitation of well-known states (850-keV (2+) state in ^{56}Fe, for example). The assigned uncertainties in Q values, dQ, were generally governed by the complexity of the nuclear structure and available resolution and indicated the energy interval associated with the specified cross-section determination. These dQ uncertainties usually exceeded the experimental scattered-neutron resolutions.

The observed structure of hafnium, gadolinium, and samarium is summarized in Table I and compared with known states in the individual isotopes in Figs. 12-14. The measured Q values and cross sections near excitation energies of 500 keV were distorted by elastically scattered neutrons originating in the second neutron group from the ^{7}Li(p,n)^{7}Be source reaction.[13] The results were corrected for this elastic contamination using the known yield of the second source group[15] and the measured elastic cross sections. This correction procedure did introduce uncertainties. Inelastic scattering of second-group neutrons introduced further uncertainties, which were particularly evident in hafnium where the second-group excitation of the 98-keV state was estimated to account for ≲20% of the observed cross section for the excitation of the 610-keV state. Similar second-group inelastic excitations were not explicitly observed in either gadolinium or samarium and were estimated to make relatively small (≲10%) contributions to the observed cross sections in the worst cases. Throughout the measurements, no corrections were made for any second-source-group inelastic scattering.

TABLE I. Energies in keV of States in Hafnium, Gadolinium, and Samarium, as Observed in the Present Inelastic Neutron Scattering Measurements[a]

Hafnium	Gadolinium	Samarium
98 ± 10	80 ± 20	100 ± 20
310 ± 50	260 ± 40	200 (?)
450 ± 50	350 ± 40	270 ± 30
525 ± 25[b]	430 ± 30	350 ± 30
610 ± 50[b]	500 ± 40(?)[b]	520 ± 50(?)[b]
800 ± 100	870 ± 50	690 ± 50
1050 ± 90	960 }	810 ± 50
1240 ± 90	1140 } 1100 ± 130	930 ± 40
	1230 }	1020 ± 30
		1090 ± 40

[a]See text for discussion of uncertainties.
[b]Contains contribution from elastic scattered neutrons originating in the second group from the ^{7}Li(p,n)^{7}Be source reaction.

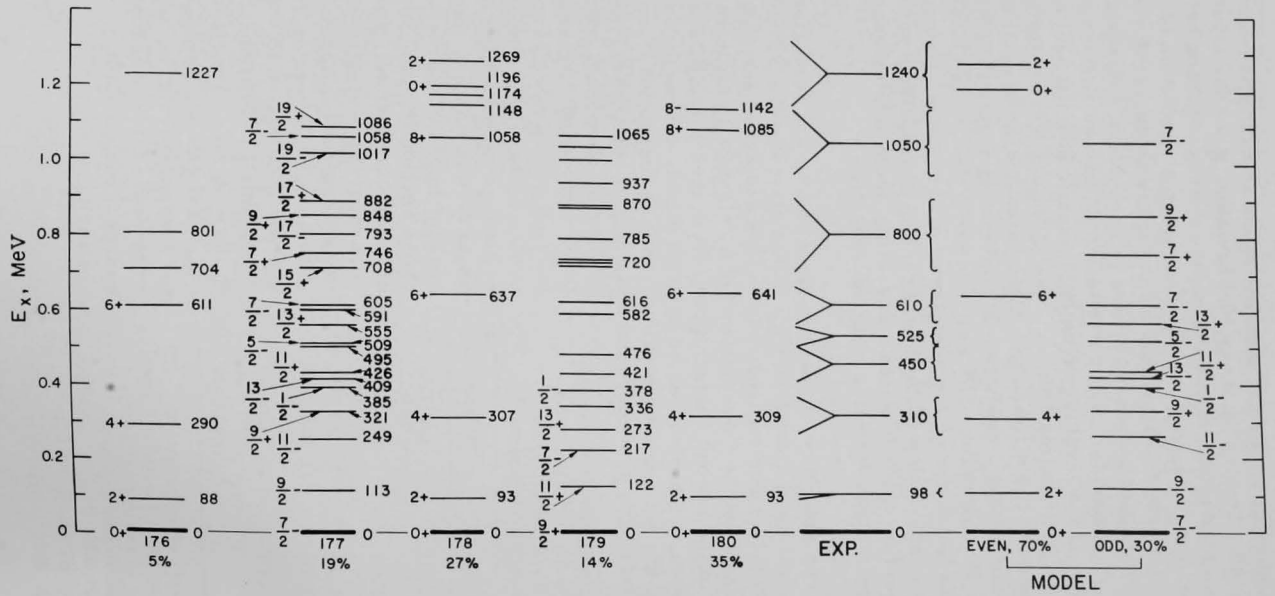

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Fig. 12. Excited Structure of Hafnium. Left, reported values.[2] Right, model used in calculations. Center, experimental observation.

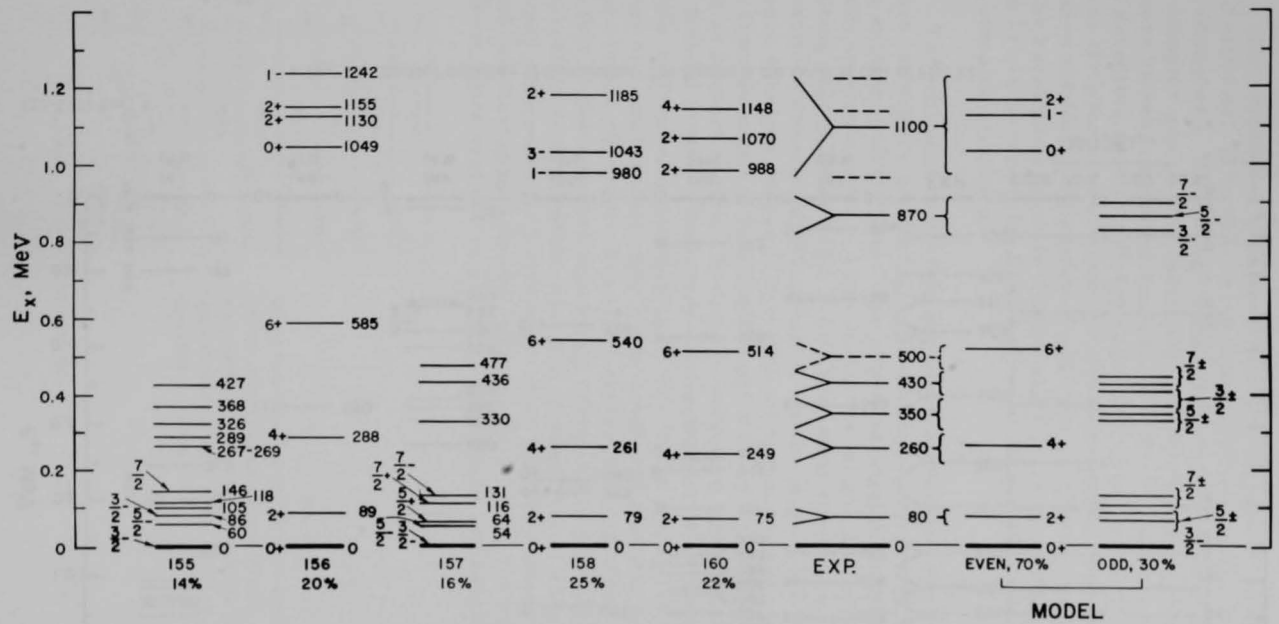

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Fig. 13. Excited Structure of Gadolinium. The format is the same as that of Fig. 12.

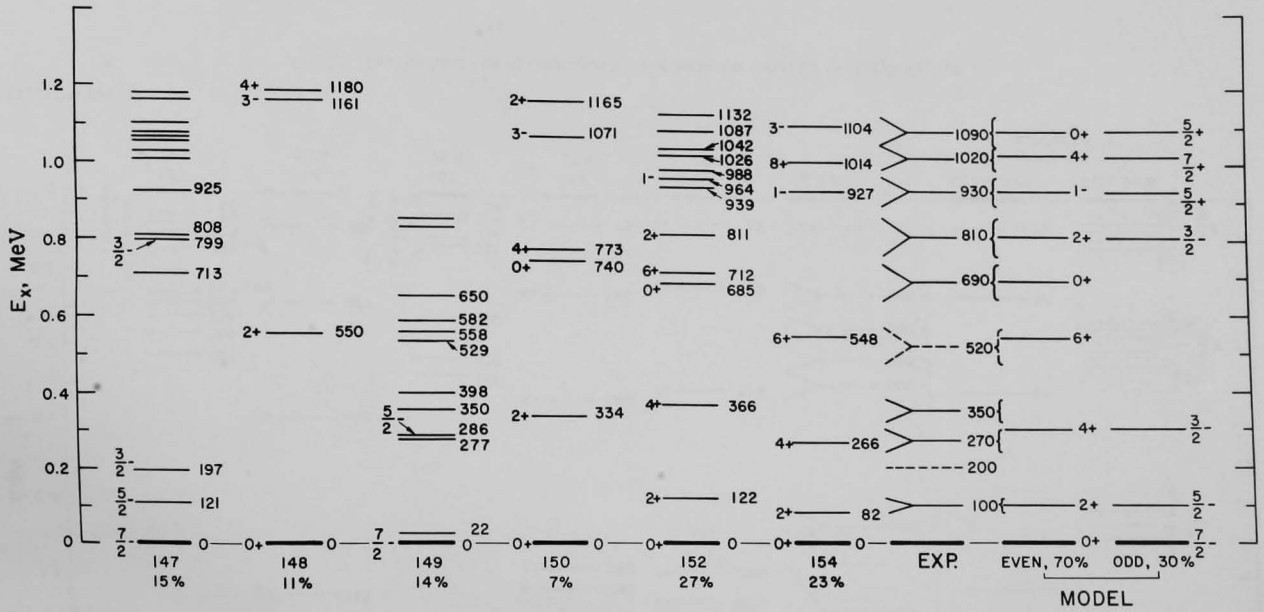

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Fig. 14. Excited Structure of Samarium. The format is the same as that of Fig. 13.

Many measured time spectra indicated that the observed "levels" were multiplets. (The 960-, 1140-, and 1230-keV states in gadolinium were acute examples.) "Unfolding" techniques could have been used to break these complex groups into individual components, particularly if the structure were known from other sources. However, such procedures could have led to deceptive results and were avoided, since the spirit of the investigation was the provision of cross sections for applied use. It was doubtful if extensive unfolding procedures would have contributed to this end. Therefore the resolutions given in Table I and the corresponding cross-section values are to be interpreted as observational quantities in the context of a more complex structure.

The inelastic scattering angular distributions were observed at eight or more laboratory scattering angles, usually concurrent with elastic scattering angular distributions. The observed angular distributions were essentially isotropic with, in some instances, slight tendencies toward forward scattering angles. (See Figs. 5-8.) The latter effect was most in evidence for reactions associated with small Q values (e.g., $\lesssim$100 keV) and at higher incidence energies, where it was difficult to resolve the inelastic neutron group from an order of magnitude more intense elastically scattered component at forward angles. The angle-integrated inelastic cross sections were derived from the measured differential cross sections by constructing a simple average and multiplying by 4π. In the context of the above observed isotropy and small anisotropy, it was estimated that this procedure incurred no more than a 5% error. Scattered neutrons of $\ll$200 keV were observed, but in this region detector sensitivity changed rapidly with energy, and cross-section determination was judged unreliable. Thus cross sections were only determined at incident energies >200 keV above the respective inelastic scattering thresholds. Figures 15-17 show the resulting inelastic excitation cross sections of hafnium, gadolinium, and samarium, respectively.

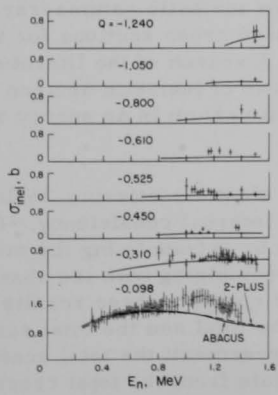

Fig. 15

Observed Inelastic-excitation Cross Sections of Hafnium. Crosses indicate measured cross sections and associated cross-section error. Observed reaction Q values in MeV are indicated. Curves are the results of calculations as described in the text.

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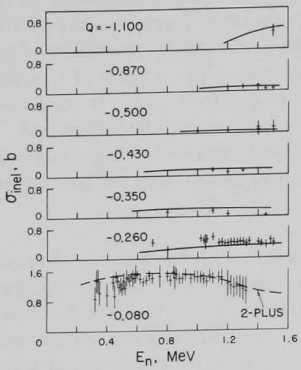

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Fig. 16. Observed Inelastic-excitation Cross Sections of Gadolinium. The notation is the same as that in Fig. 14.

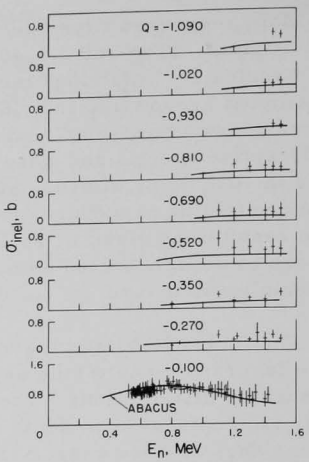

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Fig. 17. Observed Inelastic-excitation Cross Sections of Samarium. The notation is the same as that in Fig. 14.

The corresponding numerical values are listed in the appendix. The indicated uncertainties are subjective and conservative estimates due to a number of sources, including errors in the carbon reference standard.

The lack of previous experimental results made it difficult to make quantitative comparisons with the present measured inelastic values. The nonelastic cross section of hafnium reported by Walt and Barschall[7] was ~10% less than that derived from the present work. There was little correlation between the reported cross sections for inelastic gamma-ray emission from hafnium and the directly measured cross sections for inelastic scattering of the present experiment.[9] A search of the literature did not reveal any previous direct determinations of inelastic neutron scattering cross sections of either gadolinium or samarium in an energy range comparable to that of the present work.

It is of interest to examine the present elastic scattering, inelastic scattering, and total cross-section results for internal consistency. The total scattering cross sections were estimated by extrapolating the measured inelastic cross sections to threshold and combining with the observed elastic scattering cross sections. Figures 1-3 compare these results with the directly measured total cross sections. The total and the total scattering cross sections of gadolinium are in good agreement; the total scattering cross section of hafnium and of samarium deviate from the total cross section by as much as 5-6% at higher energies. These discrepancies can be

partly attributed to uncertainties associated with the second source group, discussed above. In all three elements, there are some differences between total and total scattering cross sections near the lowest measured energies. These differences are not systematic nor due to capture effects. They are believed due to uncertainties in the extrapolation of the first and relatively intense inelastic group to threshold. The low-energy discrepancies are $\lesssim 10\%$, within the respective experimental accuracies.

IV. PHYSICAL INTERPRETATION

A. Total Neutron Cross Sections and Intermediate Resonance Structure

Intermediate resonance structure has been reported in the total neutron cross sections of heavy deformed nuclei.[3] This structure has been attributed to collective "doorway" states and should be evident at low incident neutron energies where the number of available exit channels is limited.[16,17] Such structure has been particularly reported in the total cross sections of gadolinium over the energy range 0.1-0.6 MeV and was characterized by a magnitude 10-20% that of the entire total cross section and an average periodicity of ~20 keV. Such structure was not qualitatively evident in the present work, as illustrated by Figs. 1-3, though the statistical precisions and energy resolutions used here generally were superior to those used in past measurements.

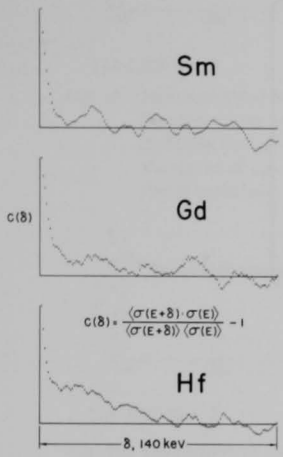
Close inspection of the present total cross-section results indicated a possible tendency toward an intermediate structure of small magnitude (a few percent). The possible existence of such structure was quantitatively assayed using the correlation function[18]

$$C(\delta) = \frac{\langle \sigma(E+\delta) \cdot \sigma(E) \rangle}{\langle \sigma(E+\delta) \rangle \cdot \langle \sigma(E) \rangle} - 1. \qquad (2)$$

$C(\delta)$ was evaluated as a function of δ over the entire measured energy interval and several subintervals thereof for the total cross sections of hafnium, gadolinium, and samarium. The measured total cross sections consisted of compound nucleus (CN) and direct reaction (DR) components. The latter were assumed to vary slowly with energy and were estimated by least-squares fitting the measured values with a cubic power series in energy. The DR cross section obtained in this manner was subtracted from the measured values, leaving a fluctuating CN contribution. This latter fluctuating cross section was assayed using Eq. 2.

Figure 18 shows representative results of the above correlation analysis of hafnium, samarium, and gadolinium. In each case, $C(\delta)$ rapidly decreases with increasing δ in a manner expected from the theoretical Lorentzian form.[18] Superimposed on this Lorentzian shape is a general oscillatory behavior, characteristic of the finite range of the experimental sample and of the predicted rms magnitude. For hafnium, there seems to be an additional component slowly decreasing with increasing values of δ. This is believed due to a residual direct reaction not fully corrected for in the above fitting procedures. Fitting with higher-order power series greatly reduced the effect. In all instances, these correlation functions indicated an apparent resonance width of 2-4 keV. This width was essentially equivalent to the experimental resolution and much larger than the characteristic CN

resonance widths. It was judged that these correlation distributions gave no quantitative evidence for resonance structure with average widths appreciably larger than that associated with the experimental resolution of 2-3 keV.



113-2032

Fig. 18

Correlation Function, C(δ), Distributions of the Form of Eq. 2 Determined from the Measured Total Neutron Cross Sections of Gadolinium, Samarium, and Hafnium

B. Calculations Using the Optical Model and Statistical Theory

The experimental results were compared with values calculated from the optical model and statistical theory.[19-22] The initial calculations used a spherical potential and established the qualitative basis for subsequent use of a deformed potential. Individual calculations for each isotope of these complex elements would have been unduly tedious. As an alternative, even and odd "models" of each element were used. (See Figs. 12-14.) The even models were reasonably consistent with the structure observed in this and other work and with the known systematics of nuclear structure.[23] The structure of the odd models was more speculative, but they were of minority natural abundance. Calculations were carried out for each element using the pair of model isotopes. The results were combined in accordance with the respective model isotopic abundance and averaged over energy intervals equivalent to the experimental resolutions for comparison with measured values. (The averaging increments are indicated by the brackets of Figs. 12-14.)

The optical potentials were adjusted to provide a subjectively judged "best" description of the total and the differential elastic neutron scattering cross sections determined in the present study. Throughout, the statistical methods of Hauser-Feshbach were used to determine compound elastic and inelastic neutron scattering cross sections.[21] When deformed potentials were used, attention was given to direct inelastic excitation processes associated with the coupling of the ground (0+) and first excited (2+) states of the even nuclei.

The spherical surface-absorption potential of Moldauer was taken as a point of departure.[24] This potential has been shown descriptive of low-energy neutron-scattering processes and strength functions. The potential has the form

$$\left.\begin{aligned} & -Vq - iWp + V_{so}\left(\frac{\hbar}{m_\pi c}\right)^2 \underline{\sigma}\cdot\underline{\ell}\,\frac{1}{r}\frac{dq}{dr}, \\ & q(r) = \left[1 + \exp\left(\frac{r-R}{a}\right)\right]^{-1}, \\ & \text{and} \\ & p(r) = \exp\left[-\left(\frac{r-R-c}{b}\right)^2\right], \end{aligned}\right\} \qquad (3)$$

where

$$R = 1.16\,A^{1/3} + 0.6\ \text{F},$$

$$a = 0.62\ \text{F},$$

$$c = 0.5\ \text{F},$$

and

$$V_{so}\ (\text{spin-orbit term}) = 7.0\ \text{MeV}.$$

Calculations were carried out using the ABACUS-NEARREX computer program.[25] V, W, and the absorption width, b, were varied to obtain the best agreement with measured elastic scattering. Table II lists the resulting "selected" parameter values. Total cross sections calculated from these parameters are reasonably descriptive of the experimental values for hafnium, gadolinium, and samarium, as indicated by the ABACUS curve of Figs. 19 and 20, for example. Further, the calculated elastic scattering is in qualitative agreement with experiment (see Figs. 9-11), though detailed comparisons with measured angular distributions reveal appreciable discrepancies, particularly at scattering angles greater than 90°. (See Figs. 5, 6, and 8.) Inelastic excitation cross sections calculated with the above spherical potentials are in fair agreement with the experimental results, as indicated in Fig. 15 (ABACUS). Detailed agreement is probably not significant other than for the excitation of the first few states, since the relation of the measured values to the model structures used in

TABLE II. "Best" Optical-model Parameters

Quantity	Samarium	Gadolinium	Hafnium
$\bar{A}$	150	156	178
V_R, MeV	42.0	43.0	44.1
W_{IM}, MeV	8.0	12.0	12.0
b, F	1.37	1.25	1.0
V_{DIR}, MeV	-	43.0	44.1
β	0.35	0.36	0.27

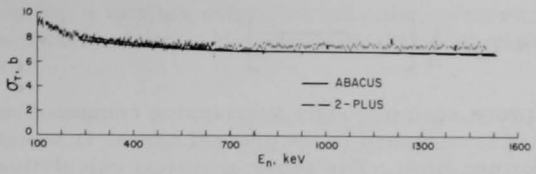


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Fig. 19. Measured Total Neutron Cross Sections (crosses) of Hafnium, Compared with Results of Spherical (ABACUS) and Deformed (2-PLUS) Optical-model Calculations. Square data points are the results of check measurements using a different (time-of-flight) technique.

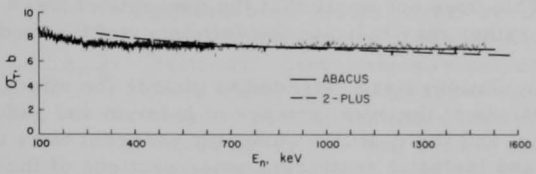

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Fig. 20. Comparison of Measured and Calculated Total Cross Sections of Gadolinium. The notation is the same as in Fig. 19.

the calculations is uncertain. However, the nonelastic cross sections derived from the calculations, from the present measurements, and as reported from previous experiments, are similar.[7] The above calculated inelastic angular distributions are symmetric about 90° and, in the present cases, nearly isotropic. (See Fig. 5, for example.) This is in agreement with the measured results, though there appears to be a systematic tendency for the largest experimental values to occur toward forward scattering angles.

Differences between measured and calculated inelastic scattering can be attributed to incorrect excited structures used in the calculations. In simple cases, it is reasonable to compare experimental results with values calculated from alternate structure assignments and thereby obtain some insight into the nuclear structure. In the context of the isotopic and structural complexity of the elements of this study, such a procedure was judged unrewarding and not attempted. Moreover, in the present work there can be little doubt that inelastic processes associated with small Q values are predominantly due to the excitation of the levels of the well-known ground-state rotational bands of the even isotopes.

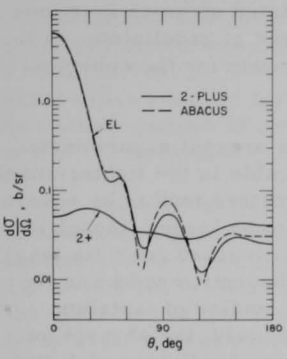
Compound nuclear processes are influenced by resonance-width fluctuations and correlations.[26] These concepts can be incorporated in the Hauser-Feshbach formulation as corrected transmission coefficients, $\langle \theta \rangle$, where

$$\langle \theta_\alpha \rangle = T_\alpha + \frac{1}{Q}\left[1 - \sqrt{1 - QT_\alpha}\right]^2 . \tag{4}$$

Q can vary between zero (strongly overlapping compound nuclear levels) and one (isolated levels), and in the present cases, Q would be expected to approach the former limit. The above spherical calculations were extended to include both limiting values of Q--zero and one--using the ABACUS-NEARREX computational program. The use of the above "corrections" did not significantly alter the calculated elastic scattering cross sections. However, the calculated cross sections for the excitations of the first (2+) state of the even isotopes were (for either choice of Q) 15% or more lower than the uncorrected Hauser-Feshbach result and in poorer agreement with experiment. This does not imply that the concepts of Eq. 4 and Ref. 26 are incorrect, but rather may indicate the deficiency of the model in other areas.

The calculations were extended to include the effects of the known static deformations of the even isotopes of hafnium and gadolinium. A deformed potential and the 2-PLUS computer program were used to calculate total, elastic, and inelastic scattering cross sections of the even model isotopes.[27] The direct excitation of the first (2+) state was explicitly considered. The excitations of higher levels in the even isotopes and all inelastic scattering from the odd isotopes were calculated with the conventional Hauser-Feshbach formula. The nuclear deformation parameter, β, was taken from the literature,[10] and the direct well was assumed equivalent to the real well. Initial attempts to determine "best" deformed potential values indicated that the parameters would be similar to those obtained for the spherical potential, and the latter were accepted for further detailed deformed calculations. (See Table II.) The calculated total cross sections were, particularly for gadolinium, in somewhat poorer agreement with experiment than those derived from the spherical potential. (See Fig. 20.) The deformed calculations did result in better agreement with experimental elastic angular distributions than those obtained from the spherical potential. (See Figs. 5, 6, 9, and 10.) This was particularly true of angular distributions at scattering angles greater than 90°. For hafnium, there were very small differences between the energy-dependent shapes and the magnitudes of the excitation cross sections of the first (2+) states as calculated using the two methods. (See Fig. 16.) For gadolinium, the two results were essentially indistinguishable, and only the 2-PLUS result is shown in Fig. 16. Generally, the calculated direct excitation of this first (2+) state was small ($\lesssim$5% of the compound nucleus contribution) at the energies of the present experiment. Thus, though the direct contribution was peaked forward, it should not have led to large asymmetries in the observable cross sections. (See Figs. 5 and 6.) Small asymmetries in the inelastic cross sections were possibly supported by the measured distributions. But, as pointed out above, it was not clear to what extent the small experimental asymmetries were due to instrumental effects. No attempt was made to incorporate the

"corrections" of Eq. 4 into the deformed potential calculations. It is reasonable to expect their effect to be similar to that of the spherical case discussed above.



113-892 Rev. 1

Fig. 21

Comparison of Calculated Elastic and Inelastic (2+) Scattering of 6.0-MeV Neutrons from Hafnium Using Spherical (ABACUS) and Deformed (2-PLUS) Potentials

At the energies of the present experiments, the contribution of the direct excitation of the first (2+) state is small. This is not true at higher incident neutron energies. Figure 21 compares elastic and inelastic (2+) scattering of 6.0-MeV neutrons from hafnium as calculated with the spherical (ABACUS) and the deformed (2-PLUS) potential. At these energies, the effect of the DR component is pronounced in the minima of the elastic cross section and in the angular distribution of the inelastic scattered neutrons. Experimental resolution of such effects would require measured scattered-neutron velocity resolutions more than an order of magnitude better than that used in the present experiments.

The spherical and the deformed optical potentials selected above were used to calculate the $\ell = 0$ strength functions of hafnium and gadolinium. Table III compares the calculated results and reported experimental values. Unfortunately, the uncertainties associated with the experimental values are large, often exceeding the difference between the two calculated results. In this mass region, the strength function is known to follow a "double humped" behavior,[3,23,28] and hafnium and gadolinium are approximately symmetrically placed on either

TABLE III. $\ell = 0$ Strength Functions of Even Isotopes of Hafnium and Gadolinium

Isotope	Experimental		Calculated
^{156}Gd	$(1.9 \pm 0.3) \times 10^{-4}$ $(1.9 \pm 0.4) \times 10^{-4}$ [a]	$(1.9 \pm 0.9) \times 10^{-4}$ [b]	2.08×10^{-4} (ABACUS)
^{158}Gd	$(2.2 \pm 1.2) \times 10^{-4}$ [c]		
Gd		$(1.5 \pm 0.3) \times 10^{-4}$ [b]	1.58×10^{-4} (2-PLUS)
^{174}Hf	$(2.8 \pm 1.3) \times 10^{-4}$ [d]		
^{176}Hf	$(1.44 \pm 0.5) \times 10^{-4}$ [d]	$(1.44 \pm 0.5) \times 10^{-4}$ [b]	2.47×10^{-4} (ABACUS)
^{178}Hf	$(2.1 \pm 0.7) \times 10^{-4}$ [d]	$(2.1 \pm 0.7) \times 10^{-4}$ [b]	
^{180}Hf	$(0.3 \pm 0.26) \times 10^{-4}$ [d]		1.73×10^{-4} (2-PLUS)
Hf		$(2.5 \pm 0.5) \times 10^{-4}$ [b]	

[a] R. Chrien and S. Mughabghab, Proc. of Antwerp Conf., p. 21 (1965).
[b] Recommend value.[3]
[c] R. Chrien, private communication as quoted in Ref. 3.
[d] T. Fuketa and J. Harvey, private communication as quoted in Ref. 3.

side of the intermediate valley. This characteristic behavior of the strength function can be interpreted in terms of nuclear deformation, and, indeed, the above deformed potential does lead to such a dependence of strength function on mass. However, comparison of calculated strength functions with the present experimental values of hafnium and of gadolinium, as in Table III, does not alone indicate any clear preference for the spherical (ABACUS) or deformed (2-PLUS) potentials.

The potential parameters derived from the present experiments differ somewhat from those found generally applicable in the lighter-mass region.[24] Both real and imaginary potential parameters tend to be several MeV smaller, and the absorption width, b, tends to be larger, though the width of the surface absorption cannot be entirely divorced from its magnitude. The tendency toward increased surface-absorption widths in the deformed nuclear region has been noted before in studies of tantalum, rhenium, platinum, and tungsten.[28,33] Very qualitatively, the absorption width appears related to the deformation parameter, β. Values of $b \cong 0.5$ F tend to be suitable for $\beta \lesssim 0.15$. The width increases from this value in a relatively linear manner as β increases beyond 0.15, reaching a value of ~1.4 F at $\beta = 0.35$.

V. COMPARISON WITH EVALUATED NUCLEAR DATA FILE-B (ENDF-B)

Since a primary motivation of the present work is the provision of cross-section data for reactor design, it is of interest to compare the present experimental results with the contents of the Evaluated Nuclear Data File-B, ENDF-B.[29-31] This file contains a relatively complete set of evaluated cross sections for hafnium and gadolinium, but only material pertinent to a single isotope of samarium (^{148}Sm). Therefore evaluated samarium data of Ref. 32 were used in the comparison with experimental results.

Figures 22-24 compare measured and evaluated total cross sections of samarium, gadolinium, and hafnium. Each figure uses the total cross section values given in BNL-325[4] to extend the present measurements from 1.5 to 10.0 MeV. The hafnium ENDF-B total cross sections tend to follow the BNL-325 values and deviate from the present results by $\lesssim$10%, particularly in the energy range 1.0-1.5 MeV. The hafnium evaluation of Ref. 32 differs somewhat from that of ENDF-B, but is in no better agreement with the present experimental results. The evaluated total cross sections of gadolinium are in better agreement with experiment than those of hafnium,

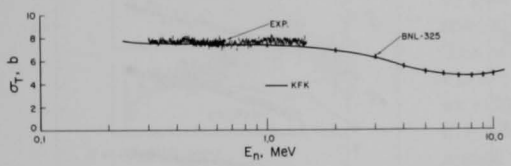


Fig. 22

Comparison of Measured and Evaluated Total Cross Sections of Samarium. Present experimental results are noted by bars. Boxes are from Ref. 4. The line labeled KFK is from the evaluated data of Ref. 32.

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Fig. 23

Comparison of Measured and Evaluated Total Cross Sections of Gadolinium. Bars denote the present experimental results, boxes the data of Ref. 4. The ENDF-B evaluation is indicated by the curve.[29]

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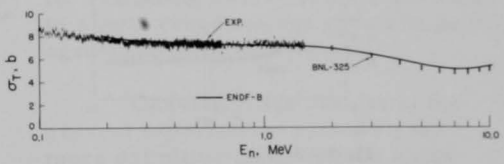

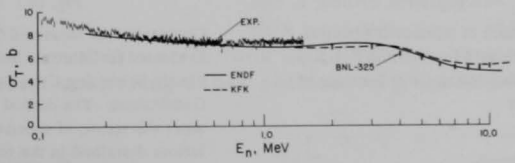

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Fig. 24. Comparison of Measured and Evaluated Total Cross Sections of Hafnium. Bars denote the present experimental results, boxes the data of Ref. 4. The solid curve shows the evaluated results of Ref. 29, and the dashed curve Ref. 32.

deviating slightly from measurement only at the lower energies. The experimental total cross sections of samarium are a little larger than the values given in Ref. 32, which follows the BNL-325 compilation.

The hafnium evaluated elastic scattering cross sections given in ENDF-B are in reasonable agreement with experiment above ~400 keV, as indicated in Fig. 25. The agreement with experiment is less satisfactory for gadolinium, as shown in Fig. 26. The evaluated total elastic scattering cross sections of gadolinium are appreciably below the measured values. Since the ENDF-B file is internally consistent, the evaluated total cross sections of gadolinium agree with the presently measured results, and the measured elastic and inelastic cross sections are reasonably consistent with the total cross sections. The discrepancy between measured and evaluated elastic scattering cross sections would be expected to persist in the inelastic scattering cross sections, as it does (see below).

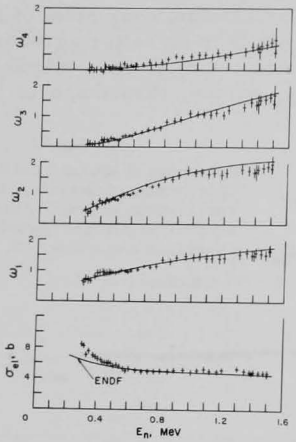

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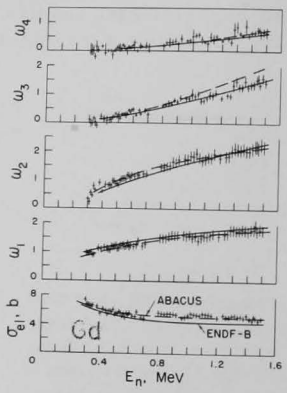
Fig. 25

Comparison of Measured (crosses) and Evaluated (curve from Ref. 29) Elastic Scattering Cross Sections of Hafnium

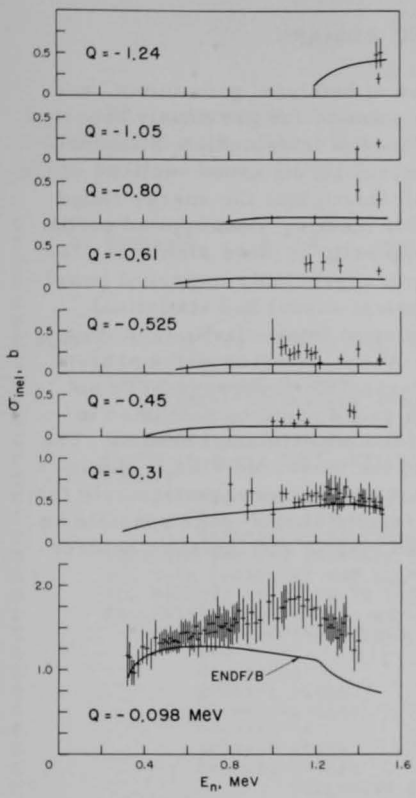


113-1923 Rev. 1

Fig. 26

Comparison of Measured (crosses) and Evaluated (solid curve from Ref. 29) Elastic Scattering Cross Sections of Gadolinium. The dashed curve denotes the results of spherical calculations described in the text.

Figure 27 compares the observed inelastic scattering cross sections of hafnium with the ENDF-B evaluated quantities. In making this comparison, we averaged the reaction Q-values of the evaluated data to make possible a comparison with the observed quantities. The evaluated data did not contain a cross section that could be reasonably associated with the excitation of the 1.05-MeV state. Generally, the evaluated and experimental



113-975 Rev. 1

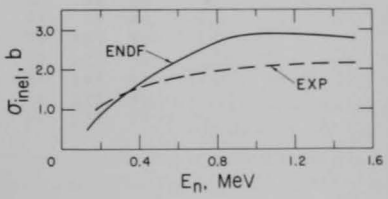
Fig. 27. Comparison of Measured (crosses) and Evaluated (curve from Ref. 29) Inelastic Excitation Cross Sections of Hafnium

inelastic scattering cross sections of hafnium are in reasonable agreement, but for the excitation of the first state (Q = -0.098 MeV). The evaluated excitation cross sections for this first state were based upon optical-model and statistical calculations and led to results appreciably below the experimental quantities, particularly at higher incident energies. A similar tendency of calculated results was noted in Section IV. No detailed experimental inelastic-excitation cross sections of gadolinium were available when the ENDF-B evaluation was carried out. As a result, the gadolinium evaluation gives only total inelastic cross sections and temperature distributions. Figure 28 compares the total inelastic scattering cross sections of gadolinium derived from the present measurements and as given in ENDF-B. The evaluated result tends to be appreciably larger than the measured values at incident neutron energies above 0.6 MeV. This discrepancy compensates for the discrepancy in the elastic scattering cross sections and leads to a total cross section rather in good agreement with experiment.

Generally, the results of the present experiments provide a far more definitive experimental basis for a sound evaluation. If used for this purpose, they would lead to modification of the evaluated cross sections of ENDF-B, particularly for the elastic and inelastic scattering cross sections of gadolinium.

Fig. 28

Total Inelastic Scattering Cross Section of Gadolinium Derived from Measurements (dashed curve), and Corresponding Values of Refs. 29 and 31



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VI. CONCLUDING REMARK

The observed total cross sections of hafnium, gadolinium, and samarium tend to be a little larger than some of the previously reported values and do not show measurable evidence of intermediate structure. Elastic and inelastic differential neutron-scattering cross sections of the three elements were determined in detail throughout the energy range 0.3-1.5 MeV. The results are suitable for meeting most applied needs. The experimental resolution and the complexity of these elements precluded extensive interpretations leading to appreciably improved knowledge of nuclear structure. Results of optical-model and statistical calculations were quantitatively descriptive of total, elastic, and, to a lesser extent, inelastic cross sections. At the energies of the present experiments, the contributions of direct-reaction processes were not pronounced. The evaluated total neutron cross sections contained in ENDF-B were reasonably descriptive of the experimental results. The agreement between the ENDF-B data and the measured elastic and inelastic scattering cross sections was less satisfactory, particularly for gadolinium. The present experimental results should make possible an appreciable improvement in the evaluated elastic and inelastic neutron-scattering data sets.

APPENDIX

Tabular Results

The experimental numerical data forming the basis for this paper are tabulated here. These data have been forwarded to the National Neutron Cross Section Center (NNCSC), Brookhaven National Laboratory.

```
C  HAFNIUM DATA BLOCK
C    G. SHERWOOD, A. SMITH, J. WHALEN---TO BE PUBLISHED
C
C
C
C
C ELASTIC SCATTERING FROM NATURAL HAFNIUM        DATE 11-68
C        FINAL VALUES
C        TIME-OF-FLIGHT METHOD
C           INCIDENT RESOLUTION ABOUT 20 KEV
C           SCATTERED RESOLUTION 1.5 NSEC/M
C        ESTIMATED ERROR IN INTEGRATED X-SEC 8 PERCENT INCLUDING STD.
C        ERROR IN OMEGA COEF. ESTIMATED FROM LEAST SQ. FITTING.
C        FORMAT
C            D X-SEC= (X-SEC/ 4*PI)*(1.+ SUM OMEGA*P)              EQ(1)
C                 SUM FROM 1-5
C                 P=LEGENDRE POLYNOMIAL IN LAB. SYSTEM
C        MEASURED ANGULAR INTERVAL 25-155 DEG. AT EIGHT ANGLES
C        ALL DATA CORRECTED FOR MULTIPLE SCATTERING
C        ALL RESULTS RELATIVE TO DIF. CARBON X-SEC OF ANL-5567(REV)
C        FOLLOWING CARD FORMAT  6X, 2I4, 5(I5,I4) , BCD
C           WHERE RESPECTIVE VALUES ARE.
C                 E-N IN KEV
C                 X-SEC*100
C                 OMEGA-1 *1000
C                 D-OMEGA-1*1000
C                 ---------
C                 OMEGA-5 *1000
C                 D-OMEGA-5*1000
C                         FOLLOWING EQ(1) ABOVE.

      300 839  621 120  470 100  100  80-0030 100
      315 820  728 120  342 100  115 100   80 100
      330 705  692 120  401  80   80  60-  10  80
      346 753  673 100  637 100  100 100    0 100
      373 695  821 100  553 100  100  80   10  80
      390 675  922 100  750  80  216 100-  60  80
      406 653  927 100  678  80  244  80  100  80
      425 635  963 100  691  60  230  60   78  80
      435 608  909 100  788  60  186  60   50  80
      450 605  932 100  740  60  280  60  100  80
      466 594  936 100  786  50  262  50   60  60
      476 602  941  80  829  50  235  50   60  60
      490 591  935  60  785  50  232  50   46  60
      506 562  924  60  783  50  227  50   25  60
      526 570  950  50  900  50  337  50  203  80
      543 555  998  50  947  50  373  50  125  80
      570 525  977  50  963  50  368  50  144  60
      585 500  950  50  940  50  360  50  120  60
      606 522  989  50  997  50  439  60  172  70
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650 504 1030  50 1080  50  475  60  170  80
690 486+1140  50+1257  50+ 557  80+ 247 100
730 493+1112  60 1206  60  591  80  194  80
770 491+1142  80 1271  80  611  80  250 100
810 500 1350 100 1452 100  808 100  350  80+ 110  80
860 494 1290 100 1448 100  853 100  438  80  100  80
900 509 1421 100 1575 120  903 100  405  80  140  80
960 513 1470 120 1735 140 1090 120  440 100  300 100
1010 482 1440 120 1660 120 1070 100  487 100  170 130
1050 507 1470 120 1680 120 1060 100  490 100  200 120
1093 523 1406 130 1617 130 1046 120  424 100  100 150
1130 498 1412 130 1655 130 1109 120  561 120  142 130
1178 495 1398 150 1600 150 1044 130  432 120  120 130
1210 515 1420 150 1670 150 1200 130  500 120  180 150
1308 530 1541 150 1780 150 1300 130  600 150  250 150
1353 502 1590 150 1741 150 1457 150  761 150  173 150
1388 486 1512 150 1679 150 1367 150  732 150  130 150
1400 475 1500 164 1700 249 1400 291  587 210  309 214
1412 487 1587 150 1782 150 1534 150  793 150  312 120
1445 480 1557 150 1831 150 1550 150  833 150  120 100
1475 480 1520 150 1870 150 1622 150  900 150  180 100
1500 450 1640 150 1809 150 1412 150  571 150  100 180
1501 480 1667 180 1950 273 1689 320  980 405  318 364

C  INELASTIC SCATTERING FROM HAFNIUM    DATE 11-68
C       FORMAT( 7E10.4)
C       RESPECTIVELY---
C        1) INCIDENT ENERGY IN MEV
C        2) UNCERTAINTY (+-) IN INCIDENT ENERGY
C        3) REACTION Q IN MEV
C        4) TOTAL UNCERTAINTY IN Q VALUE, USSUALLY INTERVAL
C              OVER WHICH CROSS SECTION IS INTEGRATED,
C        5) RESPECTIVE INELASTIC CROSS SECTION,
C        6) + ERROR IN CROSS SECTION
C        7) - ERROR IN CROSS SECTION
C       ALL DATA ASSOCIATED WITH ABOVE ELASTIC MEASUREMENTS
C       ALL DATA RELATIVE TO THE DIFFERENTIAL ELASTIC SCATTERING
C       CROSS SECTION OF CARBON--- ANL-5567(REV)
C
 HF Q=-098 KEV
 .3200E 00 .1000E-01-.9800E-01 .1000E-01 .1170E 01 .3622E 00 .3622E 00
 .3300E 00 .1000E-01-.9800E-01 .1000E-01 .1148E 01 .1722E 00 .1722E 00
 .3400E 00 .1000E-01-.9800E-01 .1000E-01 .9694E 00 .1454E 00 .1454E 00
 .3500E 00 .1000E-01-.9800E-01 .1000E-01 .9658E 00 .1449E 00 .1449E 00
 .3700E 00 .1000E-01-.9800E-01 .1000E-01 .1072E 01 .1609E 00 .1609E 00
 .3900E 00 .1000E-01-.9800E-01 .1000E-01 .1273E 01 .1909E 00 .1909E 00
 .4100E 00 .1000E-01-.9800E-01 .1000E-01 .1254E 01 .1881E 00 .1881E 00
 .4300E 00 .1000E-01-.9800E-01 .1000E-01 .1187E 01 .1781E 00 .1781E 00
 .4500E 00 .1000E-01-.9800E-01 .1000E-01 .1379E 01 .2068E 00 .2068E 00
 .4700E 00 .1000E-01-.9800E-01 .1000E-01 .1313E 01 .1138E 00 .1138E 00
 .4800E 00 .1000E-01-.9800E-01 .1000E-01 .1314E 01 .1397E 00 .1397E 00
 .4900E 00 .1000E-01-.9800E-01 .1000E-01 .1358E 01 .1178E 00 .1178E 00
 .5000E 00 .1000E-01-.9800E-01 .1000E-01 .1335E 01 .1416E 00 .1416E 00
 .5100E 00 .1000E-01-.9800E-01 .1000E-01 .1314E 01 .1140E 00 .1140E 00
 .5200E 00 .1000E-01-.9800E-01 .1000E-01 .1374E 01 .1458E 00 .1458E 00
 .5300E 00 .1000E-01-.9800E-01 .1000E-01 .1333E 01 .1155E 00 .1155E 00
 .5400E 00 .1000E-01-.9800E-01 .1000E-01 .1352E 01 .1172E 00 .1172E 00
 .5500E 00 .1000E-01-.9800E-01 .1000E-01 .1340E 01 .1419E 00 .1419E 00
 .5600E 00 .1000E-01-.9800E-01 .1000E-01 .1325E 01 .1150E 00 .1150E 00
 .5700E 00 .1000E-01-.9800E-01 .1000E-01 .1435E 01 .1522E 00 .1522E 00
 .5800E 00 .1000E-01-.9800E-01 .1000E-01 .1436E 01 .1245E 00 .1245E 00
 .5900E 00 .1000E-01-.9800E-01 .1000E-01 .1442E 01 .1530E 00 .1530E 00
 .6000E 00 .1000E-01-.9800E-01 .1000E-01 .1444E 01 .1248E 00 .1248E 00
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.6100E 00 .1000E-01-.9800E-01 .1000E-01 .1370E 01 .2050E 00 .2050E 00     114
.6200E 00 .1000E-01-.9800E-01 .1000E-01 .1393E 01 .1481E 00 .1481E 00     115
.6300E 00 .1000E-01-.9800E-01 .1000E-01 .1430E 01 .2150E 00 .2150E 00     116
.6400E 00 .1000E-01-.9800E-01 .1000E-01 .1517E 01 .1611E 00 .1611E 00     117
.6500E 00 .1000E-01-.9800E-01 .1000E-01 .1360E 01 .2040E 00 .2040E 00     118
.6600E 00 .1000E-01-.9800E-01 .1000E-01 .1428E 01 .1519E 00 .1519E 00     119
.6800E 00 .1000E-01-.9800E-01 .1000E-01 .1472E 01 .1557E 00 .1557E 00     120
.6900E 00 .1000E-01-.9800E-01 .1000E-01 .1430E 01 .2140E 00 .2140E 00     121
.7000E 00 .1000E-01-.9800E-01 .1000E-01 .1547E 01 .1643E 00 .1643E 00     122
.7100E 00 .1000E-01-.9800E-01 .1000E-01 .1440E 01 .2160E 00 .2160E 00     123
.7200E 00 .1000E-01-.9800E-01 .1000E-01 .1549E 01 .1643E 00 .1643E 00     124
.7300E 00 .1000E-01-.9800E-01 .1000E-01 .1450E 01 .2170E 00 .2170E 00     125
.7400E 00 .1000E-01-.9800E-01 .1000E-01 .1626E 01 .2439E 00 .2439E 00     126
.7500E 00 .1000E-01-.9800E-01 .1000E-01 .1520E 01 .2280E 00 .2280E 00     127
.7600E 00 .1000E-01-.9800E-01 .1000E-01 .1499E 01 .1592E 00 .1592E 00     128
.7700E 00 .1000E-01-.9800E-01 .1000E-01 .1520E 01 .2290E 00 .2290E 00     129
.7800E 00 .1000E-01-.9800E-01 .1000E-01 .1552E 01 .1650E 00 .1650E 00     130
.7900E 00 .1000E-01-.9800E-01 .1000E-01 .1480E 01 .2220E 00 .2220E 00     131
.8000E 00 .1000E-01-.9800E-01 .1000E-01 .1465E 01 .1554E 00 .1554E 00     132
.8100E 00 .1000E-01-.9800E-01 .1000E-01 .1530E 01 .2300E 00 .2300E 00     133
.8200E 00 .1000E-01-.9800E-01 .1000E-01 .1600E 01 .1695E 00 .1695E 00     134
.8300E 00 .1000E-01-.9800E-01 .1000E-01 .1560E 01 .2340E 00 .2340E 00     135
.8400E 00 .1000E-01-.9800E-01 .1000E-01 .1700E 01 .2540E 00 .2540E 00     136
.8600E 00 .1000E-01-.9800E-01 .1000E-01 .1608E 01 .2413E 00 .2413E 00     137
.8800E 00 .1000E-01-.9800E-01 .1000E-01 .1546E 01 .2319E 00 .2319E 00     138
.9000E 00 .1000E-01-.9800E-01 .1000E-01 .1679E 01 .2519E 00 .2519E 00     139
.9200E 00 .1000E-01-.9800E-01 .1000E-01 .1554E 01 .2331E 00 .2331E 00     140
.9400E 00 .1000E-01-.9800E-01 .1000E-01 .1589E 01 .2383E 00 .2383E 00     141
.9800E 00 .1000E-01-.9800E-01 .1000E-01 .1803E 01 .2705E 00 .2705E 00     142
.1000E 01 .1000E-01-.9800E-01 .1000E-01 .1878E 01 .2818E 00 .2818E 00     143
.1020E 01 .1000E-01-.9800E-01 .1000E-01 .1611E 01 .2416E 00 .2416E 00     144
.1040E 01 .1000E-01-.9800E-01 .1000E-01 .1737E 01 .1844E 00 .1844E 00     145
.1050E 01 .1000E-01-.9800E-01 .1000E-01 .1740E 01 .2610E 00 .2610E 00     146
.1060E 01 .1000E-01-.9800E-01 .1000E-01 .1809E 01 .1919E 00 .1919E 00     147
.1080E 01 .1000E-01-.9800E-01 .1000E-01 .1835E 01 .1946E 00 .1946E 00     148
.1100E 01 .1000E-01-.9800E-01 .1000E-01 .1840E 01 .1952E 00 .1952E 00     149
.1120E 01 .1000E-01-.9800E-01 .1000E-01 .1864E 01 .1977E 00 .1977E 00     150
.1140E 01 .1000E-01-.9800E-01 .1000E-01 .1757E 01 .2636E 00 .2636E 00     151
.1160E 01 .1000E-01-.9800E-01 .1000E-01 .1828E 01 .1938E 00 .1938E 00     152
.1180E 01 .1000E-01-.9800E-01 .1000E-01 .1716E 01 .1820E 00 .1820E 00     153
.1200E 01 .1000E-01-.9800E-01 .1000E-01 .1735E 01 .1503E 00 .1503E 00     154
.1220E 01 .1000E-01-.9800E-01 .1000E-01 .1528E 01 .2292E 00 .2292E 00     155
.1240E 01 .1000E-01-.9800E-01 .1000E-01 .1610E 01 .1708E 00 .1708E 00     156
.1250E 01 .1000E-01-.9800E-01 .1000E-01 .1601E 01 .2401E 00 .2401E 00     157
.1260E 01 .1000E-01-.9800E-01 .1000E-01 .1506E 01 .1598E 00 .1598E 00     158
.1270E 01 .1000E-01-.9800E-01 .1000E-01 .1533E 01 .2299E 00 .2299E 00     159
.1280E 01 .1000E-01-.9800E-01 .1000E-01 .1499E 01 .1592E 00 .1592E 00     160
.1290E 01 .1000E-01-.9800E-01 .1000E-01 .1609E 01 .2413E 00 .2413E 00     161
.1300E 01 .1000E-01-.9800E-01 .1000E-01 .1378E 01 .2068E 00 .2068E 00     162
.1310E 01 .1000E-01-.9800E-01 .1000E-01 .1470E 01 .2205E 00 .2205E 00     163
.1320E 01 .1000E-01-.9800E-01 .1000E-01 .1418E 01 .2127E 00 .2127E 00     164
.1330E 01 .1000E-01-.9800E-01 .1000E-01 .1557E 01 .2336E 00 .2336E 00     165
.1340E 01 .1000E-01-.9800E-01 .1000E-01 .1640E 01 .2460E 00 .2460E 00     166
.1360E 01 .1000E-01-.9800E-01 .1000E-01 .1432E 01 .2025E 00 .2025E 00     167
.1380E 01 .1000E-01-.9800E-01 .1000E-01 .1236E 01 .2481E 00 .2481E 00     168
.1400E 01 .1000E-01-.9800E-01 .1000E-01 .1344E 01 .2469E 00 .2469E 00     169
                                                                          170
HF Q=-310 KEV                                                             171
.8000E 00 .1000E-01-.3100E 00 .5000E-01 .6943E 00 .2041E 00 .2041E 00     172
.8800E 00 .1000E-01-.3100E 00 .5000E-01 .4500E 00 .1749E 00 .1749E 00     173
.9000E 00 .1000E-01-.3100E 00 .5000E-01 .6165E 00 .1547E 00 .1547E 00     174
.1000E 01 .1000E-01-.3100E 00 .5000E-01 .3410E 00 .1520E 00 .1520E 00     175
.1040E 01 .1000E-01-.3100E 00 .5000E-01 .5914E 00 .9871E-01 .9871E-01     176
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.1060E 01 .1000E-01-.3100E 00 .5000E-01 .5870E 00 .6931E-01 .6931E-01
.1100E 01 .1000E-01-.3100E 00 .5000E-01 .4800E 00 .6827E-01 .6827E-01
.1120E 01 .1000E-01-.3100E 00 .5000E-01 .4844E 00 .6740E-01 .6740E-01
.1140E 01 .1000E-01-.3100E 00 .5000E-01 .5158E 00 .7109E-01 .7109E-01
.1160E 01 .1000E-01-.3100E 00 .5000E-01 .5872E 00 .8085E-01 .8085E-01
.1180E 01 .1000E-01-.3100E 00 .5000E-01 .5578E 00 .6876E-01 .6876E-01
.1200E 01 .1000E-01-.3100E 00 .5000E-01 .5917E 00 .1168E 00 .1168E 00
.1220E 01 .1000E-01-.3100E 00 .5000E-01 .5527E 00 .1290E 00 .1290E 00
.1240E 01 .1000E-01-.3100E 00 .5000E-01 .5154E 00 .9246E-01 .9246E-01
.1250E 01 .1000E-01-.3100E 00 .5000E-01 .6660E 00 .1990E 00 .1990E 00
.1260E 01 .1000E-01-.3100E 00 .5000E-01 .5811E 00 .1717E 00 .1717E 00
.1270E 01 .1000E-01-.3100E 00 .5000E-01 .6395E 00 .1592E 00 .1592E 00
.1280E 01 .1000E-01-.3100E 00 .5000E-01 .4743E 00 .1031E 00 .1031E 00
.1290E 01 .1000E-01-.3100E 00 .5000E-01 .6376E 00 .1564E 00 .1564E 00
.1300E 01 .1000E-01-.3100E 00 .5000E-01 .5245E 00 .1868E 00 .1868E 00
.1310E 01 .1000E-01-.3100E 00 .5000E-01 .5891E 00 .1837E 00 .1837E 00
.1320E 01 .1000E-01-.3100E 00 .5000E-01 .4644E 00 .8206E-01 .8206E-01
.1330E 01 .1000E-01-.3100E 00 .5000E-01 .5472E 00 .1208E 00 .1208E 00
.1340E 01 .1000E-01-.3100E 00 .5000E-01 .6667E 00 .1000E 00 .1000E 00
.1360E 01 .1000E-01-.3100E 00 .5000E-01 .5475E 00 .8777E-01 .8777E-01
.1380E 01 .1000E-01-.3100E 00 .5000E-01 .4696E 00 .8112E-01 .8112E-01
.1400E 01 .1000E-01-.3100E 00 .5000E-01 .5016E 00 .8345E-01 .8345E-01
.1410E 01 .1000E-01-.3100E 00 .5000E-01 .5625E 00 .1437E 00 .1437E 00
.1420E 01 .1000E-01-.3100E 00 .5000E-01 .5318E 00 .1090E 00 .1090E 00
.1430E 01 .1000E-01-.3100E 00 .5000E-01 .4908E 00 .1361E 00 .1361E 00
.1450E 01 .1000E-01-.3100E 00 .5000E-01 .5260E 00 .1890E 00 .1890E 00
.1470E 01 .1000E-01-.3100E 00 .5000E-01 .4921E 00 .1382E 00 .1382E 00
.1480E 01 .1000E-01-.3100E 00 .5000E-01 .4442E 00 .9408E-01 .9408E-01
.1500E 01 .1000E-01-.3100E 00 .5000E-01 .4863E 00 .1257E 00 .1257E 00
.1510E 01 .1000E-01-.3100E 00 .5000E-01 .3391E 00 .2086E 00 .2086E 00

HF Q=-450 KEV
.1000E 01 .1000E-01-.4500E 00 .5000E-01 .1850E 00 .4770E-01 .4770E-01
.1040E 01 .1000E-01-.4500E 00 .5000E-01 .1780E 00 .4670E-01 .4670E-01
.1100E 01 .1000E-01-.4500E 00 .5000E-01 .1600E 00 .4390E-01 .4390E-01
.1120E 01 .1000E-01-.4500E 00 .5000E-01 .2640E 00 .5960E-01 .5960E-01
.1160E 01 .1000E-01-.4500E 00 .5000E-01 .1720E 00 .4270E-01 .4270E-01
.1360E 01 .1000E-01-.4500E 00 .5000E-01 .3150E 00 .8730E-01 .8730E-01
.1380E 01 .1000E-01-.4500E 00 .5000E-01 .2930E 00 .8390E-01 .8390E-01

HF SECOND GROUP CORRECTED, Q= ABOUT -525 KEV
.1000E 01 .1000E-01-.5250E 00 .2500E-01 .4049E 00 .2336E 00 .2336E 00
.1040E 01 .1000E-01-.5250E 00 .2500E-01 .3032E 00 .1000E 00 .1000E 00
.1060E 01 .1000E-01-.5250E 00 .2500E-01 .3257E 00 .1074E 00 .1074E 00
.1080E 01 .1000E-01-.5250E 00 .2500E-01 .2168E 00 .7154E-01 .7154E-01
.1100E 01 .1000E-01-.5250E 00 .2500E-01 .2363E 00 .7797E-01 .7797E-01
.1120E 01 .1000E-01-.5250E 00 .2500E-01 .2553E 00 .8424E-01 .8424E-01
.1160E 01 .1000E-01-.5250E 00 .2500E-01 .2628E 00 .8672E-01 .8672E-01
.1180E 01 .1000E-01-.5250E 00 .2500E-01 .2258E 00 .7451E-01 .7451E-01
.1200E 01 .1000E-01-.5250E 00 .2500E-01 .2450E 00 .8084E-01 .8084E-01
.1220E 01 .1000E-01-.5250E 00 .2500E-01 .1240E 00 .8092E-01 .8092E-01
.1320E 01 .1000E-01-.5250E 00 .2500E-01 .1710E 00 .5643E-01 .5643E-01
.1400E 01 .1000E-01-.5250E 00 .2500E-01 .2868E 00 .9464E-01 .9464E-01
.1500E 01 .1000E-01-.5250E 00 .2500E-01 .1675E 00 .5527E-01 .5527E-01
.1500E 01 .1000E-01-.5250E 00 .2500E-01 .1454E 00 .4798E-01 .4798E-01

HF Q=-610 KEV
.1160E 01 .1000E-01-.6100E 00 .5000E-01 .2790E 00 .9206E-01 .9206E-01
.1180E 01 .1000E-01-.6100E 00 .5000E-01 .2940E 00 .9702E-01 .9702E-01
.1240E 01 .1000E-01-.6100E 00 .5000E-01 .3070E 00 .1013E 00 .1013E 00
.1320E 01 .1000E-01-.6100E 00 .5000E-01 .2600E 00 .8580E-01 .8580E-01
.1500E 01 .1000E-01-.6100E 00 .5000E-01 .1982E 00 .4897E-01 .4897E-01
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HF Q= 800 KEV
.1400E 01 .1000E-01-.8000E 00 .1000E 00 .4022E 00 .1327E 00 .1327E 00
.1500E 01 .1000E-01-.8000E 00 .1000E 00 .2858E 00 .9431E-01 .9431E-01

HF Q=-1050 KEV
.1400E 01 .1000E-01-.1050E 01 .9000E-01 .1262E 00 .3155E-01 .3155E-01
.1500E 01 .1000E-01-.1050E 01 .9000E-01 .1961E 00 .4902E-01 .4902E-01


HF Q=-1240 KEV
.1490E 01 .2000E-01-.1240E 01 .9000E-01 .4790E 00 .1580E 00 .1580E 00
.1500E 01 .2000E-01-.1240E 01 .9000E-01 .2000E 00 .6600E-01 .6600E-01
.1510E 01 .2000E-01-.1240E 01 .9000E-01 .5030E 00 .1659E 00 .1659E 00

C
C
C     TOTAL CROSS SECTIONS OF HAFNIUM
C         MONOENERGETIC SOURCE METHOD
C         RESOLUTION 2-3 KEV
C         FORMAT(3E12.6)
C              ENERGY IN KEV
C              XSEC IN BARNS
C              ERROR IN XSEC IN BARNS
C
 .104499E 03 .918000E 01 .230000E 00
 .106600E 03 .942000E 01 .130000E 00
 .108600E 03 .952000E 01 .130000E 00
 .110600E 03 .920000E 01 .130000E 00
 .112700E 03 .918000E 01 .130000E 00
 .114700E 03 .921000E 01 .230000E 00
 .116700E 03 .941000E 01 .130000E 00
 .118700E 03 .899000E 01 .220000E 00
 .126800E 03 .916000E 01 .130000E 00
 .128800E 03 .910000E 01 .130000E 00
 .130900E 03 .910000E 01 .130000E 00
 .132900E 03 .909000E 01 .130000E 00
 .134900E 03 .876000E 01 .130000E 00
 .136900E 03 .907000E 01 .130000E 00
 .138900E 03 .885000E 01 .130000E 00
 .140900E 03 .889000E 01 .130000E 00
 .142900E 03 .860000E 01 .130000E 00
 .144999E 03 .891000E 01 .130000E 00
 .146999E 03 .883000E 01 .130000E 00
 .148999E 03 .867000E 01 .130000E 00
 .150999E 03 .863000E 01 .130000E 00
 .152999E 03 .876000E 01 .130000E 00
 .154999E 03 .868000E 01 .130000E 00
 .156999E 03 .886000E 01 .130000E 00
 .158999E 03 .858000E 01 .130000E 00
 .160999E 03 .885000E 01 .130000E 00
 .163100E 03 .871000E 01 .130000E 00
 .165100E 03 .873000E 01 .130000E 00
 .167100E 03 .858000E 01 .130000E 00
 .169100E 03 .845000E 01 .119999E 00
 .171100E 03 .832000E 01 .119999E 00
 .173100E 03 .846000E 01 .130000E 00
 .175100E 03 .832000E 01 .130000E 00
 .177100E 03 .849000E 01 .119999E 00
 .179100E 03 .833000E 01 .119999E 00
 .181100E 03 .810000E 01 .119999E 00
 .183100E 03 .814000E 01 .119999E 00
 .185100E 03 .857000E 01 .119999E 00
 .187200E 03 .847000E 01 .119999E 00
 .189200E 03 .808000E 01 .119999E 00
 .191200E 03 .820000E 01 .220000E 00
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.193200E 03 .824000E 01 .119999E 00
.195200E 03 .822000E 01 .119999E 00
.197200E 03 .816000E 01 .119999E 00
.199200E 03 .833000E 01 .119999E 00
.201200E 03 .794000E 01 .119999E 00
.203200E 03 .821000E 01 .119999E 00
.205200E 03 .818000E 01 .119999E 00
.207200E 03 .798000E 01 .119999E 00
.209200E 03 .783000E 01 .119999E 00
.211200E 03 .811000E 01 .119999E 00
.213200E 03 .843000E 01 .119999E 00
.217300E 03 .832000E 01 .119999E 00
.219300E 03 .815000E 01 .119999E 00
.221300E 03 .839000E 01 .119999E 00
.223300E 03 .819000E 01 .119999E 00
.225300E 03 .816000E 01 .119999E 00
.227300E 03 .824000E 01 .119999E 00
.229300E 03 .799000E 01 .119999E 00
.231300E 03 .791000E 01 .119999E 00
.233300E 03 .793000E 01 .119999E 00
.235300E 03 .788000E 01 .119999E 00
.237300E 03 .790000E 01 .119999E 00
.239300E 03 .805000E 01 .119999E 00
.241300E 03 .794000E 01 .119999E 00
.243300E 03 .811000E 01 .119999E 00
.245300E 03 .757000E 01 .119999E 00
.247300E 03 .819000E 01 .119999E 00
.249300E 03 .786000E 01 .119999E 00
.251400E 03 .799000E 01 .119999E 00
.253400E 03 .812000E 01 .119999E 00
.255400E 03 .791000E 01 .119999E 00
.257400E 03 .801000E 01 .119999E 00
.259400E 03 .762000E 01 .119999E 00
.261400E 03 .774999E 01 .119999E 00
.263400E 03 .798000E 01 .119999E 00
.265400E 03 .771000E 01 .119999E 00
.267400E 03 .761000E 01 .119999E 00
.269400E 03 .751000E 01 .119999E 00
.271400E 03 .781000E 01 .119999E 00
.273400E 03 .796000E 01 .119999E 00
.275400E 03 .772000E 01 .119999E 00
.277400E 03 .806000E 01 .220000E 00
.279400E 03 .774999E 01 .119999E 00
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.137763E	04	.727073E	01	.881160E-01	678
.138763E	04	.733560E	01	.880320E-01	679
.139264E	04	.727200E	01	.879270E-01	680
.139764E	04	.717381E	01	.880210E-01	681
.140265E	04	.736978E	01	.879780E-01	682
.140765E	04	.741296E	01	.879920E-01	683
.141265E	04	.712914E	01	.879910E-01	684
.141766E	04	.722802E	01	.879080E-01	685
.142266E	04	.724666E	01	.879030E-01	686
.142767E	04	.763760E	01	.880200E-01	687
.143267E	04	.727289E	01	.878980E-01	688
.143768E	04	.720623E	01	.879470E-01	689

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 .144268E 04 .731065E 01 .879720E-01
 .144768E 04 .716394E 01 .879040E-01
 .145269E 04 .749786E 01 .879950E-01
 .145769E 04 .725036E 01 .878340E-01
 .146270E 04 .716412E 01 .878060E-01
 .146770E 04 .723387E 01 .878560E-01
 .147270E 04 .737580E 01 .879340E-01
 .147771E 04 .768428E 01 .879370E-01
 .148271E 04 .736958E 01 .878670E-01
 .148771E 04 .700501E 01 .879320E-01
 .149272E 04 .734804E 01 .879240E-01
 .149772E 04 .722816E 01 .107579E 00

C
C
C        TOTAL CROSS SECTIONS OF HAFNIUM
C        CHECK POINTS USING TIME-OF-FLIGHT TECHNIQUE
C        FORMAT(AS PER ABOVE)
C
 .606667E 03 .731600E 01 .126000E 00
 .805737E 03 .680960E 01 .137000E 00
 .100482E 04 .721900E 01 .157000E 00
 .120405E 04 .774150E 01 .173000E 00
 .140321E 04 .720747E 01 .199000E 00

C
C  END HAFNIUM DATA BLOCK
C
C
C
C
C
C  GADOLINIUM DATA BLOCK
C    G. SHERWOOD, A. SMITH, J. WHALEN---TO BE PUBLISHED
C
C
C
C
C
C ELASTIC SCATTERING FROM NATURAL GADOLINIUM     DATE 11-68
C       FINAL VALUES
C       TIME-OF-FLIGHT METHOD
C          INCIDENT RESOLUTION ABOUT 20 KEV
C          SCATTERED RESOLUTION 1.5 NSEC/M
C       ESTIMATED ERROR IN INTEGRATED X-SEC 8 PERCENT INCLUDING STD.
C       ERROR IN OMEGA COEF. ESTIMATED FROM LEAST SQ. FITTING.
C       FORMAT
C           D X-SEC= (X-SEC/ 4*PI)*(1.+ SUM OMEGA*P)              EQ(1)
C                SUM FROM 1-5
C                P=LEGENDRE POLYNOMIAL IN LAB. SYSTEM
C       MEASURED ANGULAR INTERVAL 25-155 DEG. AT EIGHT ANGLES
C       ALL DATA CORRECTED FOR MULTIPLE SCATTERING
C       ALL RESULTS RELATIVE TO DIF. CARBON X-SEC OF ANL-5567(REV)

C       FOLLOWING CARD FORMAT  6X, 2I4, 5(I5,I4) , BCD
C          WHERE RESPECTIVE VALUES ARE,
C                E=N IN KEV
C                X-SEC*100
C                OMEGA-1 *1000
C                D-OMEGA-1*1000
C                ----------
C                OMEGA-5 *1000
C                D-OMEGA-5*1000
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FOLLOWING EQ(1) ABOVE.

300	743	97_1	97	34_0	57	113	7_0	-65	94	0	0	752
310	683	95_0	95	226	114	-17	14_1	33	188	0	0	753
320	678	966	96	548	9_1	-7	113	12	150	0	0	754
330	671	99_3	99	448	69	158	85	-201	113	0	0	755
340	653	894	89	782	115	2_1	142	150	189	0	0	756
350	666	91_1	91	65_1	65	-102	88	30	104	0	0	757
380	649	1145	114	90_0	97	222	118	156	54	0	0	758
400	551	109_0	109	605	6_0	12_1	57	-79	76	0	0	759
420	616	115_1	115	83_0	125	76	15_1	0	50	0	0	760
440	586	1128	112	829	86	96	103	0	50	0	0	761
450	540	1089	108	822	97	115	97	-140	148	0	0	762
460	582	107_1	107	805	8_0	196	8_1	0	50	0	0	763
470	587	120_3	120	97_1	97	209	5_0	28	65	0	0	764
480	577	1178	117	972	97	32_0	5_1	105	69	0	0	765
490	606	120_0	120	858	85	218	67	123	90	0	0	766
500	543	123_0	123	873	87	275	101	69	111	0	0	767
510	560	1118	111	83_0	83	157	66	64	89	0	0	768
520	549	1145	114	976	97	287	5_0	197	50	0	0	769
530	581	1216	121	1026	102	31_1	53	150	71	0	0	77_0
540	565	1216	121	1047	104	307	57	64	50	0	0	77_1
550	519	125_9	125	1058	105	273	105	1	133	0	0	772
560	545	1189	118	103_0	103	31_0	58	135	77	0	0	773
570	501	122_1	122	1165	116	436	5_0	108	63	0	0	774
580	559	128_0	128	1142	114	384	5_0	119	59	0	0	775
590	533	1187	118	1100	110	45_9	5_0	198	50	0	0	776
600	562	124_0	124	1158	115	465	77	292	102	0	0	777
620	517	1196	119	1128	112	274	5_0	0	50	0	0	778
640	512	1248	124	1176	117	428	8_0	173	108	0	0	779
650	574	1383	138	1164	116	313	5_0	159	50	0	0	78_0
680	497	121_5	121	1212	12_1	444	8_0	191	113	0	0	781
700	482	1277	127	1214	12_1	298	76	0	50	0	0	782
800	569	150_0	150	1438	143	601	6_0	170	67	0	0	783
820	557	1489	148	1442	144	63_0	63	293	65	0	0	784
840	548	150_3	150	1486	148	682	110	297	148	0	0	785
860	557	1557	155	1499	149	67_0	7_1	302	96	0	0	786
880	557	160_1	160	1637	163	804	8_0	341	105	0	0	787
900	549	1585	158	160_1	16_0	74_1	74	271	50	0	0	788
920	539	1599	159	1711	17_1	877	95	434	127	0	0	789
960	495	1597	159	1739	173	857	85	362	60	0	0	79_0
980	509	1565	156	1726	172	86_0	86	366	78	0	0	791
1000	532	1612	161	1839	183	1019	17_1	512	228	0	0	792
1020	560	151_1	151	183_0	183	943	94	542	77	0	0	793
1040	549	156_0	156	1925	192	1008	100	567	86	0	0	794
1060	538	1415	141	1784	178	766	87	396	117	0	0	795
1080	534	1514	151	168_1	168	776	77	313	50	0	0	796
1100	559	1567	156	1724	172	855	85	268	58	0	0	797
1120	550	1557	155	179_0	179	988	124	493	160	0	0	798
1140	547	160_1	160	1764	176	954	116	412	155	0	0	799
1160	537	1644	164	1922	192	106_0	106	506	87	0	0	800
1200	502	158_2	158	1777	177	875	87	357	58	0	0	801
1240	539	163_2	163	1826	182	976	97	429	77	0	0	802
1260	514	1665	166	1845	184	947	94	309	96	0	0	803
1280	515	1789	178	2023	202	1324	185	759	239	0	0	804
1300	531	1788	178	2122	212	1459	147	838	189	0	0	805
1320	534	1764	176	208_1	208	1267	126	628	63	0	0	806
1340	515	1777	177	2049	204	124_0	124	535	54	0	0	807
1360	520	1811	181	2085	208	1463	175	866	230	0	0	808
1380	503	1783	178	2022	202	125_1	125	538	85	0	0	809
1400	538	1744	174	2022	202	1329	132	650	74	0	0	810
1420	488	1804	180	2098	209	1335	133	638	92	0	0	811
1440	472	1814	181	218_1	218	1514	15_1	733	121	0	0	812
1450	524	1945	194	2193	219	1553	155	752	75	0	0	813
1460	505	1754	175	2115	211	1339	133	598	135	0	0	814
1480	466	1823	182	225_1	225	1577	157	666	122	0	0	815
1500	490	1778	177	2163	216	1418	141	652	171	0	0	816

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818

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C  INELASTIC SCATTERING FROM GADOLINIUM DATE 11-68
C        FORMAT( 7E10.4)
C        RESPECTIVELY--
C         1) INCIDENT ENERGY IN MEV
C         2) UNCERTAINTY (+-) IN INCIDENT ENERGY
C         3) REACTION Q IN MEV
C         4) TOTAL UNCERTAINTY IN Q VALUE, USSUALLY INTERVAL
C              OVER WHICH CROSS SECTION IS INTEGRATED.
C         5) RESPECTIVE INELASTIC CROSS SECTION.
C         6) + ERROR IN CROSS SECTION
C         7) - ERROR IN CROSS SECTION
C        ALL DATA ASSOCIATED WITH ABOVE ELASTIC MEASUREMENTS
C        ALL DATA RELATIVE TO THE DIFFERENTIAL ELASTIC SCATTERING
C        CROSS SECTION OF CARBON-- ANL-5567(REV)
C
GD Q--0,080
 .3200E 00 .1000E-01-.8000E-01 .2000E-01 .8728E 00 .3309E 00 .3309E 00
 .3300E 00 .1000E-01-.8000E-01 .2000E-01 .1343E 01 .3014E 00 .3014E 00
 .3400E 00 .1000E-01-.8000E-01 .2000E-01 .1350E 01 .3025E 00 .3025E 00
 .3500E 00 .1000E-01-.8000E-01 .2000E-01 .1021E 01 .3121E 00 .3121E 00
 .4000E 00 .1000E-01-.8000E-01 .2000E-01 .9700E 00 .3000E 00 .3000E 00
 .4400E 00 .1000E-01-.8000E-01 .2000E-01 .1312E 01 .1942E 00 .1942E 00
 .4500E 00 .1000E-01-.8000E-01 .2000E-01 .9338E 00 .3121E 00 .3121E 00
 .4600E 00 .1000E-01-.8000E-01 .2000E-01 .1445E 01 .1448E 00 .1448E 00
 .4700E 00 .1000E-01-.8000E-01 .2000E-01 .1345E 01 .1426E 00 .1426E 00
 .4800E 00 .1000E-01-.8000E-01 .2000E-01 .1176E 01 .1764E 00 .1764E 00
 .4900E 00 .1000E-01-.8000E-01 .2000E-01 .1244E 01 .1866E 00 .1866E 00
 .5000E 00 .1000E-01-.8000E-01 .2000E-01 .1130E 01 .1734E 00 .1734E 00
 .5100E 00 .1000E-01-.8000E-01 .2000E-01 .1345E 01 .2017E 00 .2017E 00
 .5200E 00 .1000E-01-.8000E-01 .2000E-01 .1155E 01 .1733E 00 .1733E 00
 .5300E 00 .1000E-01-.8000E-01 .2000E-01 .1421E 01 .2131E 00 .2131E 00
 .5400E 00 .1000E-01-.8000E-01 .2000E-01 .1410E 01 .1049E 00 .1049E 00
 .5500E 00 .1000E-01-.8000E-01 .2000E-01 .1341E 01 .1422E 00 .1422E 00
 .5600E 00 .1000E-01-.8000E-01 .2000E-01 .1457E 01 .1093E 00 .1093E 00
 .5700E 00 .1000E-01-.8000E-01 .2000E-01 .1405E 01 .2108E 00 .2108E 00
 .5800E 00 .1000E-01-.8000E-01 .2000E-01 .1413E 01 .1335E 00 .1335E 00
 .5900E 00 .1000E-01-.8000E-01 .2000E-01 .1532E 01 .2299E 00 .2299E 00
 .6000E 00 .1000E-01-.8000E-01 .2000E-01 .1498E 01 .1018E 00 .1018E 00
 .6200E 00 .1000E-01-.8000E-01 .2000E-01 .1380E 01 .1171E 00 .1171E 00
 .6400E 00 .1000E-01-.8000E-01 .2000E-01 .1303E 01 .1105E 00 .1105E 00
 .6600E 00 .1000E-01-.8000E-01 .2000E-01 .1354E 01 .1148E 00 .1148E 00
 .6800E 00 .1000E-01-.8000E-01 .2000E-01 .1471E 01 .1250E 00 .1250E 00
 .7000E 00 .1000E-01-.8000E-01 .2000E-01 .1398E 01 .1257E 00 .1257E 00
 .7500E 00 .1000E-01-.8000E-01 .2000E-01 .1450E 01 .3000E 00 .3000E 00
 .7999E 00 .1000E-01-.8000E-01 .2000E-01 .1453E 01 .1437E 00 .1437E 00
 .8200E 00 .1000E-01-.8000E-01 .2000E-01 .1345E 01 .1427E 00 .1427E 00
 .8400E 00 .1000E-01-.8000E-01 .2000E-01 .1561E 01 .1656E 00 .1656E 00
 .8499E 00 .1000E-01-.8000E-01 .2000E-01 .1410E 01 .3000E 00 .3000E 00
 .8600E 00 .1000E-01-.8000E-01 .2000E-01 .1499E 01 .1590E 00 .1590E 00
 .8800E 00 .1000E-01-.8000E-01 .2000E-01 .1383E 01 .1468E 00 .1468E 00
 .8999E 00 .1000E-01-.8000E-01 .2000E-01 .1389E 01 .1397E 00 .1397E 00
 .9200E 00 .1000E-01-.8000E-01 .2000E-01 .1482E 01 .1571E 00 .1571E 00
 .9566E 00 .1000E-01-.8000E-01 .2000E-01 .1383E 01 .1392E 00 .1392E 00
 .9800E 00 .1000E-01-.8000E-01 .2000E-01 .1431E 01 .1518E 00 .1518E 00
 .1000E 01 .1000E-01-.8000E-01 .2000E-01 .1422E 01 .1508E 00 .1508E 00
 .1020E 01 .1000E-01-.8000E-01 .2000E-01 .1421E 01 .1507E 00 .1507E 00
 .1040E 01 .1000E-01-.8000E-01 .2000E-01 .1371E 01 .1454E 00 .1454E 00
 .1060E 01 .1000E-01-.8000E-01 .2000E-01 .1302E 01 .1249E 00 .1249E 00
 .1080E 01 .1000E-01-.8000E-01 .2000E-01 .1463E 01 .1551E 00 .1551E 00
 .1100E 01 .1000E-01-.8000E-01 .2000E-01 .1392E 01 .1477E 00 .1477E 00
 .1140E 01 .1000E-01-.8000E-01 .2000E-01 .1412E 01 .1498E 00 .1498E 00
 .1160E 01 .1000E-01-.8000E-01 .2000E-01 .1406E 01 .2091E 00 .2091E 00
 .1200E 01 .1000E-01-.8000E-01 .2000E-01 .1246E 01 .3322E 00 .3322E 00
 .1220E 01 .1000E-01-.8000E-01 .2000E-01 .1188E 01 .2560E 00 .2560E 00
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 .1240E 01 .1000E-01-.8000E-01 .2000E-01 .1132E 01 .2702E 00 .2702E 00
 .1260E 01 .1000E-01-.8000E-01 .2000E-01 .1169E 01 .2526E 00 .2526E 00
 .1280E 01 .1000E-01-.8000E-01 .2000E-01 .1155E 01 .2826E 00 .2826E 00
 .1300E 01 .1000E-01-.8000E-01 .2000E-01 .1095E 01 .3010E 00 .3010E 00
 .1320E 01 .1000E-01-.8000E-01 .2000E-01 .1043E 01 .3602E-00 .3602E-00

GD Q=-260+-40 KEV,
 .7000E 00 .1000E-01-.2600E 00 .4000E-01 .4315E 00 .9470E-01 .9470E-01
 .8000E 00 .1000E-01-.2600E 00 .4000E-01 .2346E 00 .9519E-01 .9519E-01
 .1020E 01 .1000E-01-.2600E 00 .4000E-01 .5215E 00 .9532E-01 .9532E-01
 .1040E 01 .1000E-01-.2600E 00 .4000E-01 .4691E 00 .9979E-01 .9979E-01
 .1050E 01 .1000E-01-.2600E 00 .4000E-01 .4350E 00 .2000E 00 .2000E 00
 .1060E 01 .1000E-01-.2600E 00 .4000E-01 .5064E 00 .9595E-01 .9595E-01
 .1100E 01 .1000E-01-.2600E 00 .4000E-01 .5616E 00 .9963E-01 .9963E-01
 .1140E 01 .1000E-01-.2600E 00 .4000E-01 .4037E 00 .9281E-01 .9281E-01
 .1160E 01 .1000E-01-.2600E 00 .4000E-01 .4220E 00 .9476E-01 .9476E-01
 .1180E 01 .1000E-01-.2600E 00 .4000E-01 .3826E 00 .9059E-01 .9059E-01
 .1199E 01 .1000E-01-.2600E 00 .4000E-01 .3948E 00 .9661E-01 .9661E-01
 .1220E 01 .1000E-01-.2600E 00 .4000E-01 .4212E 00 .9468E-01 .9468E-01
 .1240E 01 .1000E-01-.2600E 00 .4000E-01 .4180E 00 .9434E-01 .9434E-01
 .1260E 01 .1000E-01-.2600E 00 .4000E-01 .4077E 00 .9621E-01 .9621E-01
 .1280E 01 .1000E-01-.2600E 00 .4000E-01 .4407E 00 .9034E-01 .9034E-01
 .1300E 01 .1000E-01-.2600E 00 .4000E-01 .4265E 00 .9202E-01 .9202E-01
 .1320E 01 .1000E-01-.2600E 00 .4000E-01 .3877E 00 .9113E-01 .9113E-01
 .1340E 01 .1000E-01-.2600E 00 .4000E-01 .4366E 00 .9633E-01 .9633E-01
 .1400E 01 .1000E-01-.2600E 00 .4000E-01 .4182E 00 .9249E-01 .9249E-01
 .1420E 01 .1000E-01-.2600E 00 .4000E-01 .3836E 00 .9069E-01 .9069E-01
 .1450E 01 .1000E-01-.2600E 00 .4000E-01 .3472E 00 .9683E-01 .9683E-01
 .1480E 01 .1000E-01-.2600E 00 .4000E-01 .4683E 00 .9161E-01 .9161E-01
 .1500E 01 .1000E-01-.2600E 00 .4000E-01 .3968E 00 .9726E-01 .9726E-01

 GD Q=-350  +- 40 KEV  WEAK
 .8000E 00 .1000E-01-.3500E 00 .4000E-01 .1361E 00 .8042E-01 .8042E-01
 .1100E 01 .1000E-01-.3500E 00 .4000E-01 .1584E 00 .8480E-01 .8480E-01
 .1200E 01 .1000E-01-.3500E 00 .4000E-01 .6686E-01 .3900E-01 .3900E-01
 .1450E 01 .1000E-01-.3500E 00 .4000E-01 .3472E-01 .3683E-01 .3683E-01

 GD Q= -430 +- 30 KEV  WEAK
 .1100E 01 .1000E-01-.4300E 00 .3000E-01 .1483E 00 .5990E-01 .5990E-01
 .1200E 01 .1000E-01-.4300E 00 .3000E-01 .9128E-01 .5047E-01 .5047E-01
 .1300E 01 .1000E-01-.4300E 00 .3000E-01 .1210E 00 .5628E-01 .5628E-01

GD Q=-500+-30, VERY DOUBTFUL 2ND GROUP CORR.
 .1400E 01 .2000E-01-.5000E 00 .4000E-01 .8704E-01 .1575E 00 .1575E 00
 .1500E 01 .2000E-01-.5000E 00 .4000E-01 .1430E 00 .1514E 00 .1514E 00
 .1400E 01 .2000E-01-.5000E 00 .4000E-01 .1418E 00 .1571E 00 .1571E 00


GD Q=-870+-50 KEV
 .1300E 01 .1000E-01-.8700E 00 .5000E-01 .1154E 00 .5886E-01 .5886E-01
 .1400E 01 .1000E-01-.8700E 00 .5000E-01 .1437E 00 .5096E-01 .5096E-01
 .1450E 01 .1000E-01-.8700E 00 .5000E-01 .5255E-01 .4162E-01 .4162E-01
 .1500E 01 .1000E-01-.8700E 00 .5000E-01 .6740E-01 .4348E-01 .4348E-01

GD Q= COMPOSITE OF STATES NEAR 1.10+-0.1 MEV
 1.500+000 2.000-002-1.100+000 2.000-002 4.700-001 1.535-001 1.535-001

C
C
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C     TOTAL CROSS SECTIONS OF GADOLINIUM
C         MONOENERGETIC SOURCE METHOD
C         RESOLUTION 2-3 KEV
C         FORMAT(3E12.6)
C               ENERGY IN KEV
C               XSEC IN BARNS
C               ERROR IN XSEC IN BARNS
C
 .999999E 02 .863000E 01 .150000E 00
 .101100E 03 .869000E 01 .150000E 00
 .102100E 03 .866000E 01 .150000E 00
 .103100E 03 .840000E 01 .150000E 00
 .104100E 03 .858000E 01 .150000E 00
 .105100E 03 .868000E 01 .150000E 00
 .106200E 03 .831000E 01 .140000E 00
 .107200E 03 .831000E 01 .150000E 00
 .108200E 03 .811000E 01 .140000E 00
 .109200E 03 .836000E 01 .140000E 00
 .110200E 03 .824000E 01 .140000E 00
 .111200E 03 .809000E 01 .140000E 00
 .112300E 03 .835000E 01 .140000E 00
 .114300E 03 .818000E 01 .140000E 00
 .115300E 03 .863000E 01 .140000E 00
 .116300E 03 .842000E 01 .140000E 00
 .117300E 03 .844000E 01 .140000E 00
 .118300E 03 .815000E 01 .140000E 00
 .119300E 03 .870000E 01 .140000E 00
 .120300E 03 .811000E 01 .140000E 00
 .121300E 03 .824000E 01 .140000E 00
 .122400E 03 .832000E 01 .140000E 00
 .123400E 03 .799999E 01 .140000E 00
 .124400E 03 .819000E 01 .140000E 00
 .125400E 03 .785000E 01 .140000E 00
 .126400E 03 .789000E 01 .140000E 00
 .127400E 03 .864000E 01 .140000E 00
 .128400E 03 .813000E 01 .140000E 00
 .129400E 03 .823000E 01 .140000E 00
 .130400E 03 .845000E 01 .140000E 00
 .131400E 03 .819000E 01 .140000E 00
 .132400E 03 .820000E 01 .140000E 00
 .133400E 03 .846000E 01 .140000E 00
 .134400E 03 .812000E 01 .140000E 00
 .135400E 03 .793000E 01 .140000E 00
 .136400E 03 .809000E 01 .140000E 00
 .137499E 03 .809000E 01 .140000E 00
 .138499E 03 .797000E 01 .140000E 00
 .139499E 03 .821000E 01 .140000E 00
 .140499E 03 .829000E 01 .140000E 00
 .141499E 03 .807000E 01 .140000E 00
 .142499E 03 .839000E 01 .140000E 00
 .143499E 03 .816000E 01 .140000E 00
 .144499E 03 .819000E 01 .140000E 00
 .145499E 03 .790000E 01 .140000E 00
 .146499E 03 .781000E 01 .140000E 00
 .147499E 03 .796000E 01 .140000E 00
 .148499E 03 .801000E 01 .140000E 00
 .149499E 03 .780000E 01 .140000E 00
 .150499E 03 .786000E 01 .140000E 00
 .151499E 03 .817000E 01 .140000E 00
 .152499E 03 .804000E 01 .140000E 00
 .153499E 03 .801000E 01 .140000E 00
 .154499E 03 .790000E 01 .140000E 00
 .155499E 03 .767000E 01 .140000E 00
 .156600E 03 .765000E 01 .249999E 00
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.157600E	03	.779000E	01	.140000E	00	1005
.158600E	03	.808000E	01	.140000E	00	1006
.159600E	03	.771000E	01	.140000E	00	1007
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.524200E	03	.745000E	01	.140000E	00	1366
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.527200E	03	.735000E	01	.140000E	00	1369
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.535200E	03	.714000E	01	.140000E	00	1377
.536200E	03	.729000E	01	.140000E	00	1378
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.538200E	03	.743000E	01	.140000E	00	1380
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.625200E 03 .720000E 01 .140000E 00
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 .149337E 04 .749825E 01 .948070E-01
 .149837E 04 .725394E 01 .948080E-01
C
C
C        TOTAL CROSS SECTIONS OF GADOLINIUM
C        CHECK POINTS USING TIME-OF-FLIGHT TECHNIQUE
C        FORMAT( AS PER ABOVE )
C
 .606667E 03 .697800E 01 .135000E 00
 .805737E 03 .696000E 01 .146000E 00
+.100482E+04+.747100E+01+.167000E+00
 .120405E 04 .671800E 01 .183000E 00
 .140321E 04 .694400E 01 .212000E 00
C
C  END GADOLINIUM DATA BLOCK
C
C
C
C
C

C  SAMARIUM DATA BLOCK
C    G. SHERWOOD, A. SMITH, J. WHALEN---TO BE PUBLISHED
C
C
C
C
C
C ELASTIC SCATTERING FROM NATURAL SAMARIUM       DATE 11-68
C       FINAL VALUES
C       TIME-OF-FLIGHT METHOD
C          INCIDENT RESOLUTION ABOUT 20 KEV
C          SCATTERED RESOLUTION 1.5 NSEC/M
C       ESTIMATED ERROR IN INTEGRATED X-SEC A PERCENT INCLUDING STD.
C       ERROR IN OMEGA COEF. ESTIMATED FROM LEAST SQ. FITTING.
C       FORMAT
C           D X-SEC= (X-SEC/ 4*PI)*(1.+ SUM OMEGA*P)            EQ(1)
C               SUM FROM 1-5
C               P=LEGENDRE POLYNOMIAL IN LAB. SYSTEM
C       MEASURED ANGULAR INTERVAL 25-155 DEG. AT EIGHT ANGLES
C       ALL DATA CORRECTED FOR MULTIPLE SCATTERING
C       ALL RESULTS RELATIVE TO DIF. CARBON X-SEC OF ANL-5567(REV)
C       FOLLOWING CARD FORMAT  6X, 2I4, 5(I5,I4) , BCD
C          WHERE RESPECTIVE VALUES ARE,
C               E-N IN KEV
C               X-SEC*100
C               OMEGA-1 *1000
C               D-OMEGA-1*1000
C               ----------
C               OMEGA-5 *1000
C               D-OMEGA*5*1000
C                       FOLLOWING EQ(1) ABOVE.

      303 618  887  88  381  57  105  69  -30  90
      325 657  934  93  471  86  194 105   21 141    0   0
      345 616  914  91  697  69  114  55  213  74    0   0
      365 645  820  82  734  73  -57  63  108  84    0   0
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385 628  838  83  717  72  115  88  180 118    0   0
405 607  980  98  759  75  222  70  169  94    0   0
425 593  887  88  771  77   84  72  -39  96    0   0
446 623  940  94  790  79  159  83    7 102    0   0
465 590 1011 101  874  87  155  50   25  50    0   0
485 643  933  93  821  82  184  60   82  80    0   0
505 615  931  93  883  88  175  74  -25  99    0   0
525 618  905  90  874  87  214  50   -1  50    0   0
545 620  972  97  945  94  226  60   90  80    0   0
565 631 1033 103 1004 100  265  50   97  54    0   0
585 607 1014 101 1039 103  232  50   24  50    0   0
605 624 1019 101 1019 101  207 100  125  67    0   0
620 659 1004 100 1123 112  236 100  171  55    0   0
646 622 1057 105 1090 109  328 100  110  51    0   0
665 607 1026 102 1112 111  302 100  157  50    0   0
685 609 1055 105 1177 117  332 106   80  88    0   0
705 597 1083 108 1168 116  314 100   63  50    0   0
725 592 1061 106 1178 117  241 103   87  72    0   0
755 601 1093 109 1224 122  406 103  148  70    0   0
775 558 1078 197 1270 127  357 135  -16  87    0   0
795 570 1125 192 1350 135  470 133  109  97    0   0
815 565 1177 197 1344 134  506 150  208 120    0   0
860 567 1355 195 1506 150  687 126  391 169    0   0
880 573 1345 194 1542 154  636  76  277 102    0   0
900 578 1412 191 1664 166  729 122  271  52    0   0
920 555 1419 191 1707 170  825 115  478 154    0   0
940 530 1438 193 1721 172  825 158  494 211    0   0
980 576 1408 190 1764 176  875 152  467 150    0   0
1000 564 1335 193 1755 175  858 128  491 171    0   0
1020 521 1332 193 1767 176  933  93  527 157    0   0
1040 561 1387 198 1866 186  975  97  587 162
1080 565 1348 194 1733 173  811 161  414 105
1100 597 1448 194 1811 181  950  95  466 153    0   0
1120 557 1425 142 1771 177  979  97  547 153
1140 576 1478 147 1782 178  930  93  434 100
1160 540 1448 144 1853 185 1016 151  495 158
1180 539 1438 143 1779 177  870 157  288 145
1200 556 1495 149 1880 188  995  99  441 142
1220 568 1515 151 1819 181  945 144  367 150    0   0
1240 586 1470 147 1853 185  866 146  357 150
1260 550 1500 150 1950 195  950 165  360 200    0   0
1300 547 1594 159 1817 181  926 172  397 165   18 167
1320 551 1643 164 1973 197 1190 169  647 150    0   0
1340 558 1674 167 2081 208 1285 128  562 150  130 162
1360 560 1731 173 2122 212 1379 149  723 192  350 263
1400 546 1703 170 2173 217 1364 136  749 150  158 159
1420 517 1896 189 2316 231 1464 146  777 133  421 185
1440 518 1695 169 2253 225 1435 143  853 185  211 170
1460 564 1698 169 2210 221 1399 139  683 168  306 186
1480 532 1737 173 2133 213 1549 154  695 150  150 150
1500 538 1821 182 2281 228 1538 153  682 150  470 120

C  INELASTIC SCATTERING FROM SAMARIUM    DATE 11-68
C       FORMAT( 7E10.4)
C       RESPECTIVELY---
C        1) INCIDENT ENERGY IN MEV
C        2) UNCERTAINTY (+-) IN INCIDENT ENERGY
C        3) REACTION Q IN MEV
C        4) TOTAL UNCERTAINTY IN Q VALUE, USSJALLY INTERVAL
C             OVER WHICH CROSS SECTION IS INTEGRATED.
C        5) RESPECTIVE INELASTIC CROSS SECTION.
C        6) + ERROR IN CROSS SECTION
C        7) - ERROR IN CROSS SECTION
C       ALL DATA ASSOCIATED WITH ABOVE ELASTIC MEASUREMENTS
```

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C        ALL DATA RELATIVE TO THE DIFFERENTIAL ELASTIC SCATTERING                1773
C        CROSS SECTION OF CARBON--- ANL-5567(REV)                                1774
C                                                                                1775
C     SM Q=-100 KEV                                                              1776
 .5200E 00 .2000E-01-.1000E 00 .2000E-01 .8848E 00 .1806E 00 .1806E 00           1777
 .5400E 00 .2000E-01-.1000E 00 .2000E-01 .8339E 00 .1251E 00 .1251E 00           1778
 .5450E 00 .2000E-01-.1000E 00 .2000E-01 .7948E 00 .1192E 00 .1192E 00           1779
 .5500E 00 .2000E-01-.1000E 00 .2000E-01 .8785E 00 .1098E 00 .1098E 00           1780
 .5550E 00 .2000E-01-.1000E 00 .2000E-01 .8630E 00 .1294E 00 .1294E 00           1781
 .5600E 00 .2000E-01-.1000E 00 .2000E-01 .8303E 00 .1245E 00 .1245E 00           1782
 .5650E 00 .2000E-01-.1000E 00 .2000E-01 .8220E 00 .1233E 00 .1233E 00           1783
 .5700E 00 .2000E-01-.1000E 00 .2000E-01 .8165E 00 .1224E 00 .1224E 00           1784
 .5750E 00 .2000E-01-.1000E 00 .2000E-01 .8605E 00 .1290E 00 .1290E 00           1785
 .5800E 00 .2000E-01-.1000E 00 .2000E-01 .8918E 00 .1337E 00 .1337E 00           1786
 .5850E 00 .2000E-01-.1000E 00 .2000E-01 .8857E 00 .1328E 00 .1328E 00           1787
 .5900E 00 .2000E-01-.1000E 00 .2000E-01 .8761E 00 .1314E 00 .1314E 00           1788
 .5950E 00 .2000E-01-.1000E 00 .2000E-01 .9292E 00 .1393E 00 .1393E 00           1789
 .6000E 00 .2000E-01-.1000E 00 .2000E-01 .8459E 00 .1175E 00 .1175E 00           1790
 .6050E 00 .2000E-01-.1000E 00 .2000E-01 .7658E 00 .1148E 00 .1148E 00           1791
 .6100E 00 .2000E-01-.1000E 00 .2000E-01 .7719E 00 .1157E 00 .1157E 00           1792
 .6150E 00 .2000E-01-.1000E 00 .2000E-01 .9535E 00 .1430E 00 .1430E 00           1793
 .6200E 00 .2000E-01-.1000E 00 .2000E-01 .8075E 00 .1211E 00 .1211E 00           1794
 .6249E 00 .2000E-01-.1000E 00 .2000E-01 .8332E 00 .1249E 00 .1249E 00           1795
 .6300E 00 .2000E-01-.1000E 00 .2000E-01 .9639E 00 .1445E 00 .1445E 00           1796
 .6350E 00 .2000E-01-.1000E 00 .2000E-01 .9543E 00 .1431E 00 .1431E 00           1797
 .6400E 00 .2000E-01-.1000E 00 .2000E-01 .8224E 00 .1233E 00 .1233E 00           1798
 .6450E 00 .2000E-01-.1000E 00 .2000E-01 .9941E 00 .1491E 00 .1491E 00           1799
 .6500E 00 .2000E-01-.1000E 00 .2000E-01 .8775E 00 .1097E 00 .1097E 00           1800
 .6550E 00 .2000E-01-.1000E 00 .2000E-01 .8197E 00 .1229E 00 .1229E 00           1801
 .6600E 00 .2000E-01-.1000E 00 .2000E-01 .8345E 00 .1252E 00 .1252E 00           1802
 .6650E 00 .2000E-01-.1000E 00 .2000E-01 .8782E 00 .1317E 00 .1317E 00           1803
 .6700E 00 .2000E-01-.1000E 00 .2000E-01 .8410E 00 .1261E 00 .1261E 00           1804
 .6750E 00 .2000E-01-.1000E 00 .2000E-01 .1042E 01 .1562E 00 .1562E 00           1805
 .6800E 00 .2000E-01-.1000E 00 .2000E-01 .9347E 00 .1402E 00 .1402E 00           1806
 .6850E 00 .2000E-01-.1000E 00 .2000E-01 .8865E 00 .1329E 00 .1329E 00           1807
 .6900E 00 .2000E-01-.1000E 00 .2000E-01 .8959E 00 .1344E 00 .1344E 00           1808
 .7050E 00 .2000E-01-.1000E 00 .2000E-01 .8775E 00 .7761E-01 .7761E-01           1809
 .7200E 00 .2000E-01-.1000E 00 .2000E-01 .1018E 01 .1272E 00 .1272E 00           1810
 .7300E 00 .2000E-01-.1000E 00 .2000E-01 .8749E 00 .1093E 00 .1093E 00           1811
 .7500E 00 .2000E-01-.1000E 00 .2000E-01 .9083E 00 .1135E 00 .1135E 00           1812
 .7700E 00 .2000E-01-.1000E 00 .2000E-01 .1123E 01 .1403E 00 .1403E 00           1813
 .7800E 00 .2000E-01-.1000E 00 .2000E-01 .1049E 01 .1311E 00 .1311E 00           1814
 .7900E 00 .2000E-01-.1000E 00 .2000E-01 .9915E 00 .1239E 00 .1239E 00           1815
 .7999E 00 .2000E-01-.1000E 00 .2000E-01 .9543E 00 .1192E 00 .1192E 00           1816
 .8100E 00 .2000E-01-.1000E 00 .2000E-01 .1109E 01 .1386E 00 .1386E 00           1817
 .8199E 00 .2000E-01-.1000E 00 .2000E-01 .9117E 00 .1139E 00 .1139E 00           1818
 .8300E 00 .2000E-01-.1000E 00 .2000E-01 .1035E 01 .1293E 00 .1293E 00           1819
 .8399E 00 .2000E-01-.1000E 00 .2000E-01 .1013E 01 .1266E 00 .1266E 00           1820
 .8499E 00 .2000E-01-.1000E 00 .2000E-01 .1024E 01 .1280E 00 .1280E 00           1821
 .8600E 00 .2000E-01-.1000E 00 .2000E-01 .8997E 00 .1124E 00 .1124E 00           1822
 .8800E 00 .2000E-01-.1000E 00 .2000E-01 .9142E 00 .1142E 00 .1142E 00           1823
 .8999E 00 .2000E-01-.1000E 00 .2000E-01 .9269E 00 .1158E 00 .1158E 00           1824
 .9200E 00 .2000E-01-.1000E 00 .2000E-01 .8780E 00 .1097E 00 .1097E 00           1825
 .9400E 00 .2000E-01-.1000E 00 .2000E-01 .9351E 00 .1168E 00 .1168E 00           1826
 .9498E 00 .2000E-01-.1000E 00 .2000E-01 .8640E 00 .1500E 00 .1500E 00           1827
 .9800E 00 .2000E-01-.1000E 00 .2000E-01 .9594E 00 .1199E 00 .1199E 00           1828
 .1000E 01 .2000E-01-.1000E 00 .2000E-01 .9458E 00 .1182E 00 .1182E 00           1829
 .1040E 01 .2000E-01-.1000E 00 .2000E-01 .8832E 00 .1104E 00 .1104E 00           1830
 .1050E 01 .2000E-01-.1000E 00 .2000E-01 .8850E 00 .2000E 00 .2000E 00           1831
 .1060E 01 .2000E-01-.1000E 00 .2000E-01 .8936E 00 .1117E 00 .1117E 00           1832
 .1080E 01 .2000E-01-.1000E 00 .2000E-01 .8147E 00 .2000E 00 .2000E 00           1833
 .1100E 01 .2000E-01-.1000E 00 .2000E-01 .8945E 00 .2000E 00 .2000E 00           1834
 .1120E 01 .2000E-01-.1000E 00 .2000E-01 .8827E 00 .2000E 00 .2000E 00           1835
 .1140E 01 .2000E-01-.1000E 00 .2000E-01 .7841E 00 .2000E 00 .2000E 00           1836
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.1180E 01 .2000E-01-.1000E 00 .2000E-01 .7116E 00 .2000E 00 .2000E 00
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.1300E 01 .2000E-01-.1000E 00 .2000E-01 .7145E 00 .2000E 00 .2000E 00
.1320E 01 .2000E-01-.1000E 00 .2000E-01 .6277E 00 .2000E 00 .2000E 00
.1340E 01 .2000E-01-.1000E 00 .2000E-01 .8069E 00 .2000E 00 .2000E 00
.1400E 01 .2000E-01-.1000E 00 .2000E-01 .6321E 00 .2000E 00 .2000E 00
.1420E 01 .2000E-01-.1000E 00 .2000E-01 .7447E 00 .2000E 00 .2000E 00

C    SM Q=-270 KEV
.8000E 00 .2000E-01-.2700E 00 .3000E-01 .1477E 00 .5216E-01 .5216E-01
.8499E 00 .2000E-01-.2700E 00 .3000E-01 .2110E 00 .4194E-01 .4194E-01
.1100E 01 .2000E-01-.2700E 00 .3000E-01 .4100E 00 .1000E 00 .1000E 00
.1200E 01 .2000E-01-.2700E 00 .3000E-01 .2830E 00 .5456E-01 .5456E-01
.1220E 01 .2000E-01-.2700E 00 .3000E-01 .3627E 00 .8441E-01 .8441E-01
.1300E 01 .2000E-01-.2700E 00 .3000E-01 .2810E 00 .5000E-01 .5000E-01
.1350E 01 .2000E-01-.2700E 00 .3000E-01 .4510E 00 .2500E 00 .2500E 00
.1400E 01 .2000E-01-.2700E 00 .3000E-01 .3050E 00 .1500E 00 .1500E 00
.1450E 01 .2000E-01-.2700E 00 .3000E-01 .4000E 00 .1000E 00 .1000E 00
.1500E 01 .2000E-01-.2700E 00 .3000E-01 .2960E 00 .1000E 00 .1000E 00

C    SM Q=-350 KEV
.8000E 00 .2000E-01-.3500E 00 .3000E-01 .1385E 00 .6078E-01 .6078E-01
.1100E 01 .2000E-01-.3500E 00 .3000E-01 .3601E 00 .7493E-01 .7493E-01
.1200E 01 .2000E-01-.3500E 00 .3000E-01 .2000E 00 .7538E-01 .7538E-01
.1300E 01 .2000E-01-.3500E 00 .3000E-01 .2600E 00 .5000E-01 .5000E-01
.1400E 01 .2000E-01-.3500E 00 .3000E-01 .2260E 00 .9000E-01 .9000E-01
.1500E 01 .2000E-01-.3500E 00 .3000E-01 .4060E 00 .9930E-01 .9930E-01

C    SM Q=-520 KEV, QUESTIONABLE
.1100E 01 .2000E-01-.5200E 00 .5000E-01 .6661E 00 .2058E 00 .2058E 00
.1200E 01 .2000E-01-.5200E 00 .5000E-01 .4133E 00 .2000E 00 .2000E 00
.1300E 01 .2000E-01-.5200E 00 .5000E-01 .4430E 00 .2000E 00 .2000E 00
.1400E 01 .2000E-01-.5200E 00 .5000E-01 .3618E 00 .2000E 00 .2000E 00
.1450E 01 .2000E-01-.5200E 00 .5000E-01 .4297E 00 .2000E 00 .2000E 00
.1500E 01 .2000E-01-.5200E 00 .5000E-01 .3824E 00 .2000E 00 .2000E 00

C    SM Q=-690 KEV
.1100E 01 .2000E-01-.6900E 00 .5000E-01 .2867E 00 .1545E 00 .1545E 00
.1200E 01 .2000E-01-.6900E 00 .5000E-01 .2367E 00 .1045E 00 .1045E 00
.1300E 01 .2000E-01-.6900E 00 .5000E-01 .2709E 00 .1500E 00 .1500E 00
.1400E 01 .2000E-01-.6900E 00 .5000E-01 .2675E 00 .1500E 00 .1500E 00
.1450E 01 .2000E-01-.6900E 00 .5000E-01 .2253E 00 .1500E 00 .1500E 00
.1500E 01 .2000E-01-.6900E 00 .5000E-01 .3119E 00 .1500E 00 .1500E 00

  SM Q=-810 KEV
.1200E 01 .2000E-01-.8100E 00 .5000E-01 .3676E 00 .1200E 00 .1200E 00
.1300E 01 .2000E-01-.8100E 00 .5000E-01 .2900E 00 .1200E 00 .1200E 00
.1400E 01 .2000E-01-.8100E 00 .5000E-01 .3100E 00 .1200E 00 .1200E 00
.1450E 01 .2000E-01-.8100E 00 .5000E-01 .2800E 00 .1200E 00 .1200E 00
.1500E 01 .2000E-01-.8100E 00 .5000E-01 .2710E 00 .1200E 00 .1200E 00

C    SM Q= 930 KEV
.1450E 01 .2000E-01-.9300E 00 .4000E-01 .2982E 00 .9789E-01 .9789E-01
.1500E 01 .2000E-01-.9300E 00 .4000E-01 .2751E 00 .9914E-01 .9914E-01

C    SM Q=-1020 KEV
.1400E 01 .2000E-01-.1020E 01 .3000E-01 .2663E 00 .9257E-01 .9257E-01
.1450E 01 .2000E-01-.1020E 01 .3000E-01 .2527E 00 .9011E-01 .9011E-01
.1500E 01 .2000E-01-.1020E 01 .3000E-01 .3190E 00 .9336E-01 .9336E-01
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C     SM Q=-1090 KEV
 .1450E 01 .2000E-01-.1090E 01 .4000E-01 .4996E 00 .9000E-01 .9000E-01
 .1500E 01 .2000E-01-.1090E 01 .4000E-01 .4416E 00 .9496E-01 .9496E-01
C
C
C     TOTAL CROSS SECTIONS OF SAMARIUM
C         MONOENERGETIC SOURCE METHOD
C         RESOLUTION 2-3 KEV
C         FORMAT(3E12.6)
C               ENERGY IN KEV
C               XSEC IN BARNS
C               ERROR IN XSEC IN BARNS
C
 .301499E 03 .795000E 01 .130000E 00
 .303499E 03 .785000E 01 .130000E 00
 .305499E 03 .768000E 01 .230000E 00
 .307499E 03 .764000E 01 .130000E 00
 .309499E 03 .767000E 01 .130000E 00
 .311499E 03 .773000E 01 .130000E 00
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 .315499E 03 .770000E 01 .130000E 00
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.415700E 03	.780000E 01	.130000E 00	1972
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.605900E 03 .746000E 01 .140000E 00
.607900E 03 .776000E 01 .140000E 00
.609900E 03 .731000E 01 .140000E 00
.611900E 03 .755000E 01 .140000E 00
.613900E 03 .761000E 01 .140000E 00
.615900E 03 .737000E 01 .140000E 00
.617900E 03 .803000E 01 .140000E 00
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.621900E 03 .767000E 01 .140000E 00
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