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FAST-NEUTRON SCATTERING FROM TANTALUM, RHENIUM, AND PLATINUM

by

A. B. Smith, P. T. Guenther,
R. Hayes, and J. F. Whalen

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Reactor Physics Division

August 1967

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ABSTRACT

The scattering of neutrons with energies of ≤ 1.5 MeV from tantalum, rhenium, and platinum was studied experimentally. Elastic and inelastic neutron-scattering angular distributions were determined at incident neutron-energy intervals of ≤ 20 keV throughout the range 0.3 to 1.5 MeV. Time-of-flight measurements were made concurrently at eight or more scattering angles between 25 and 155° with sufficient scattered neutron-energy resolution to separate the elastic scattered component from most inelastic scattered neutron groups. Differential inelastic scattering cross sections were observed corresponding to the excitation of states: in tantalum at 144 ± 10 (doublet), 313 ± 15 , 506 ± 20 , 620 ± 20 , 720 ± 20 , and 930 ± 25 keV; in rhenium at 132 ± 10 , 219 ± 15 , 313 ± 15 , 387 ± 18 , 518 ± 20 , 637 ± 20 , 767 ± 25 , 865 ± 25 , 963 ± 25 , 1060 ± 25 , and 1135 ± 25 keV; and in platinum at 130 ± 20 , 214 ± 20 , 348 ± 15 , 420 ± 15 , 620 ± 20 , 719 ± 15 , 838 ± 25 , and 935 ± 20 keV. The experimental results were compared with calculations based upon the optical model and the Hauser-Feshbach formula inclusive of corrections for resonance-width fluctuations. The experimentally observed level structure is discussed in the context of single-particle and rotational states of deformed nuclei.

I. INTRODUCTION

The study of fast-neutron scattering from heavy nuclei can provide an insight into the validity of the optical model and statistical concepts in regions of appreciable deformation, free from the complexities of Coulomb effects. Calculation of neutron scattering using deformed potentials is particularly difficult for odd A nuclei. Thus it is desirable to determine to what extent a spherical potential approximation is valid for the calculation of neutron scattering from deformed nuclei. With this objective, it is useful to examine neutron scattering from nuclei of similar masses

but large and differing deformations. The elements tantalum, rhenium, and platinum consist of such nuclei. They are similar in mass and charge, but vary in deformation, δ , from ~ 0.3 (Ta) to ~ 0.15 (Pt).¹ Previous experimental studies of neutron scattering from these elements have been largely confined to a few incident neutron energies and/or have provided little knowledge of the inelastically scattered neutron spectrum.³⁻¹² Because of this limited experimental base, quantitative comparison with calculation has been difficult.¹³⁻²⁰

The low-energy excited structures of tantalum, rhenium, and platinum are characterized by collective rotational-vibrational and by single-particle states.² A wealth of structure information pertinent to these elements has been reported, particularly as the result of radioactive decay and Coulomb excitation studies.²¹⁻²⁴ Despite this fund of knowledge, there remain significant discrepancies between the structure reported from experiment and the theoretical predictions.

The present experiments attempt to provide quantitative knowledge of fast-neutron scattering from tantalum, rhenium, and platinum of such quality and scope as to form a foundation for the development and assay of calculational methods and results. The measured values are used to determine spherical optical potentials, which, together with compound nucleus theory, provide calculated cross sections in quantitative agreement with experiment, permit the extrapolation and interpolation of measured values, and furnish a mechanism for correlating observed and theoretically predicted excited nuclear structure. The intent of this study is to contribute to the understanding of the structure of the isotopes of tantalum, rhenium, and platinum, particularly those facets best studied through the observation of inelastic neutron scattering. In addition, the experimental results are of extensive value in applied nuclear-energy programs since tantalum and rhenium are structural materials with excellent high-temperature properties.

II. EXPERIMENTAL METHOD

The neutron-scattering measurements were carried out with an automated multiangle time-of-flight system and an associated pulsed and bunched Van de Graaff accelerator.²⁵ This laboratory system, its use, and the associated data-handling procedures have been described in detail; thus the apparatus and method will only be outlined here.

The positive-ion pulsed Van de Graaff and associated magnetic bunching system were capable of producing ~ 1 -nsec proton bursts with peak intensities of $\lesssim 10$ mA.^{26,27} The proton bursts were converted into essentially monoenergetic neutron bursts by means of the $\text{Li}^7(p,n)\text{Be}^7$ source reaction.²⁸ The neutron-scattering samples were fabricated from the elemental material in the form of right cylinders 2 cm long and

2 cm in diameter, or 1.8 cm long and 1.8 cm in diameter. These samples were placed ~10 cm from the neutron source at a zero-degree source reaction angle. The sample-source geometry and the thicknesses of the lithium-source targets were arranged to provide incident neutron-energy spreads at the scattering samples of 10 to 30 keV. The choice of incident neutron-energy definition was dictated by the objectives of the particular measurement. Scattered neutron-time spectra were determined concurrently in eight or more detectors placed 2 to 3 m from the scattering samples. The detectors were distributed over laboratory scattering angles between 25 and 155°. Neutron source intensities were monitored with a number of "long counters" placed at various reaction angles including zero degrees.²⁹

The above apparatus provided a scattered neutron sensitivity of a few millibarns per steradian and a scattered neutron-energy resolution of ≥ 15 keV. Time spectra arbitrarily selected from a large number of measurements are shown in Fig. 1. These results are typical of those used in determinations of elastic and inelastic scattering angular distributions and respective differential cross sections.

Fig. 1

Time Spectra Obtained by Scattering Neutrons from Tantalum, Rhenium, and Platinum. Time per channel was ~1.05 nsec, and flight path ~2.0 m. Q values are indicated. Small backgrounds have been subtracted, and all spectra normalized to the same elastic peak height. No detector-sensitivity corrections have been applied, and all detector biases were chosen to emphasize the resolution of scattering resulting in the excitation of low-lying states. The vertical bars indicate the statistical standard deviations of the measurements.

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All measured cross sections were determined relative to the known elastic scattering cross sections of carbon.³ The experimental information was sufficiently processed, on line, using a digital computer to ensure a reasonable quality of the data. Subsequent off-line data processing included: reduction of observed time spectra to cross sections, corrections for incident beam attenuation and multiple scattering within the samples, and corrections for scattered neutron angular resolution.²⁵ The final corrected cross sections were made available in numerical and graphical form.

Where total cross-section values reported in the literature were in qualitative disagreement with the cumulative sums of elastic and inelastic scattering results of this work (tantalum), or where reported total cross sections were sparse (rhenium), total cross sections were measured directly. These were transmission measurements employing the

$\text{Li}^7(p,n)\text{Be}^7$ reaction as a neutron source.³⁰ The lithium targets and the experimental geometries were arranged to provide the desired neutron resolutions. Neutron detection was accomplished either with liquid scintillators employing pulse-shape discrimination for gamma-ray rejection or with a shielded battery of BF_3 proportional counters. The measurements were carried out in a fully automatic manner using a digital computer for on-line data acquisition and reduction, and feedback control to the nuclear accelerator, sample changer, and other portions of the apparatus.³¹

III. EXPERIMENTAL RESULTS

A. Elastic Scattering

Differential elastic neutron scattering cross sections were determined at eight or more scattering angles in the interval 25 to 155°. The measurements were not always made with identical scattering angles, but the angles were accurately determined for each experimental arrangement. Measurements were made at $\lesssim 20$ -keV incident-neutron-energy intervals from 0.3 to 1.5 MeV with incident-neutron-energy resolutions of ~ 20 keV. At incident neutron energies of $\lesssim 1.2$ MeV, the elastically scattered neutrons were resolved from essentially all inelastic contributions (see Fig. 1, for example). An exception was scattering from tantalum, where inelastic processes resulting in the excitation of the first state at ~ 6 keV were not resolved from the elastic contribution.²¹ At incident neutron energies > 1.2 MeV it was occasionally necessary to correct the observed elastic scattering results for contributions from inelastic scattering leaving the residual nucleus in the first excited state. These corrections were determined from careful measurements at incident energies > 1.2 MeV employing particularly long (3 to 4 m) flight paths and a limited number of scattering angles. Where necessary, these corrections were based upon calculational extrapolation of the measured inelastic scattering results (see Sec. IV below).

The experimental differential elastic scattering cross sections were expressed as Legendre expansions of the form

$$\frac{d\sigma}{d\Omega} = \frac{\sigma}{4\pi} \left[1 + \sum_{i=1}^5 \omega_i P_i \right], \quad (1)$$

where σ is the elastic scattering cross section, ω_i are coefficients of the expansion of the angular distributions in terms of Legendre polynomials, P_i , and all angles are expressed in the laboratory system. Values of ω_i and σ were obtained from a least-squares fit of Eq. 1 to the measured distributions. Expressed in the form of Eq. 1, the results were representative of the actual measured differential elastic cross sections, as

illustrated in Fig. 2, and permitted easy comparison of measurements made with slightly different experimental configurations, particularly scattering angles. Results in the form of Eq. 1 should be extrapolated with caution beyond the measured angular interval. Moreover, the experimental ω_i values may not exactly correspond to those obtained from a potential calculation as scattering angles near 0 and 180° were inaccessible to the experiment.

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Fig. 2. Differential Elastic and Inelastic Cross Sections for the Scattering of 750-keV Neutrons from Tantalum (left) and 850-keV Neutrons from Platinum (right). The measured elastic values are compared with the least-squares fit of Eq. 1 to the data. Measured inelastic cross sections for the excitation of 144- and 313-keV states in tantalum and 130-, 214-, 348-, and 420-keV states in platinum are indicated.

The experimental differential elastic scattering results for tantalum, rhenium, and platinum, expressed in the form of Eq. 1, are given in Figs. 3-5 and in Tables I-III.* The errors associated with the measurements were difficult to assay quantitatively as the determinations were complex and often subject to appreciable human judgment. However, we subjectively estimated that the elastic scattering cross sections were determined to $\pm 8\%$ with a 90% confidence, inclusive of uncertainties in the standard cross sections of carbon and possible errors in multiple scattering and other correction factors. The stated ω_i errors (DW1 in the notation of Tables I-III) are standard deviations derived from the least-squares fitting procedures and thus are only indicative of the quality of the fit of Eq. 1 to the individual experimental measurements. The consistency of the experimental results was good over an extended period (~ 4 yr).

*The tabular results referred to throughout this report are contained in the appendix.

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Fig. 3. Differential Elastic Scattering Cross Sections of Tantalum Expressed as Legendre Expansions in the Form of Eq. 1. The solid curves are the result of calculations discussed in Sec. IV. The distributions are inclusive of inelastic scattering exciting the ~ 6 -keV state in tantalum.

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Fig. 4. Differential Elastic Scattering Cross Sections of Rhenium. Format is that of Fig. 3. The curves indicate the results of theoretical calculations using various optical potentials, as discussed in Sec. IV.

112-8481

Fig. 5. Differential Elastic Scattering Cross Sections of Platinum. Format is that of Fig. 3. The solid curves indicate the results of optical model calculations (see Sec. IV); the dashed lines correspond to the same calculations corrected for resonance-width fluctuation effects.

B. Inelastic Neutron Scattering

Inelastic scattering cross sections were determined using a variety of experimental conditions chosen to emphasize particular aspects of the processes. Well-resolved inelastic neutron angular distributions were obtained for scattered neutron energies in the interval ~ 250 to ~ 1500 keV. Scattered neutrons with energies of < 250 keV were qualitatively observed, but the quantitative magnitudes of the respective cross sections were uncertain because of rapid variations in the neutron-detector sensitivities with scattered neutron energy. For this reason, scattering cross sections are not given for scattered neutron energies of ≤ 250 keV. The experimental resolution was not sufficient to separate all inelastically scattered neutron groups. Closely spaced groups were occasionally observed as scattering from a single "average" state. Thus inelastic scattering cross sections are here reported for the excitation of separate states and/or combinations of states in the elemental material as is pertinent to the particular measurements and experimental resolutions.

A few of the observed inelastic differential angular distributions tended toward forward scattering. An acute example is the excitation of the first two states in tantalum, as shown in Fig. 2. Most often, the observed inelastic angular distributions were essentially isotropic, as indicated for platinum in Fig. 2. The measured differential inelastic cross sections were averaged and multiplied by 4π to obtain the respective inelastic excitation cross sections. This procedure was judged to introduce $< 10\%$ error in the most anisotropic cases, and usually the error incurred was appreciably less than 5%. We could not always determine the differential cross sections for the inelastic excitation of low-lying states at very forward angles. This was due to an inability to clearly resolve the inelastic component from the relatively intense elastic group. When this problem became serious, the forward ($\leq 30^\circ$) differential inelastic cross sections were not used in deducing the inelastic excitation cross sections.

Inelastic neutron groups corresponding to states in tantalum at 144 ± 10 , 313 ± 15 , 506 ± 20 , 620 ± 20 , 720 ± 20 , and 930 ± 25 keV were observed. Careful measurements, such as shown in Fig. 1, indicated the 144-keV state was a doublet with a separation of 15 to 22 keV. Qualitatively, the excitation of the lower-energy state of the doublet was ~ 1.6 times more intense than that of the higher-energy state. The observation of the energy and excitation of the state at 506 keV was complicated by the presence of the second group of neutrons from the $\text{Li}^7(p,n)\text{Be}^7$ source reaction elastically scattered from the sample. The measured values were corrected for contributions due to this "second elastic" component.²⁸ Inelastic scattering of this second source component could make small contributions to other observed inelastic processes. Such perturbations were assayed and found to be small. Therefore no corrections were made. The cross sections for the inelastic excitation of the above states in tantalum, derived from the

measurements in the manner described, are shown in Fig. 6 and listed in Table IV. Figure 7 compares the excited structure of tantalum, as derived from these experiments, with that reported in Ref. 21. The excited-state energies were determined using time-scale calibrations and reference reactions such as the inelastic excitation of the well-established 846-keV state in Fe^{56} .²¹ The energies of the excited states were conservatively estimated to the specified precisions.

Fig. 6

Inelastic Excitation Cross Sections of Tantalum. Experimental points pertaining to the respective Q values (in MeV) are shown by crosses, which are indicative of estimated error in cross section and incident neutron-energy resolution. Solid lines are the results of calculations based upon the structure reported in Ref. 21. The dashed lines were obtained using the structure "MODEL" of Fig. 7. Dotted curves were obtained by applying fluctuation correction to the MODEL calculations. The lower portion of the figure indicates the calculated (not experimental) excitation of the first state at 0.006 MeV.

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Fig. 7. Experimentally Observed Structure in Tantalum (center), Compared with That Reported in Ref. 21 (right) and That of MODEL Discussed in Sec. IV.

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Fig. 8. Measured Inelastic Excitation Cross Sections of Rhenium. The data points indicate the measured quantities for the reaction Q values (in MeV). The curves represent the results of calculations extending through the excitation of the 865-keV state as described in Sec. IV.

112-8224

Fig. 9. A Comparison of the Excited Structure of Rhenium Observed in This Work with That Reported in Ref. 21.

Inelastic scattering from rhenium was observed corresponding to the excitation of states at 132 ± 10 , 219 ± 15 , 313 ± 15 , 387 ± 18 , 518 ± 20 , 637 ± 20 , 767 ± 25 , 865 ± 25 , 963 ± 25 , 1060 ± 25 , and 1135 ± 25 keV. The measured excitation cross sections are shown in Fig. 8 and listed in Table V. Figure 9 compares the observed structure with that reported in Ref. 21. There was some indication that the "state" at 132 keV was complex. The above remarks pertaining to the measurement of the 506-keV state in tantalum apply to observation of the 518-keV state in rhenium.

Inelastic neutron groups observed as a result of scattering from platinum corresponded to excitation of states at 130 ± 20 , 214 ± 20 , 348 ± 15 , 420 ± 15 , 620 ± 20 , 719 ± 15 , 838 ± 25 , and 935 ± 20 keV. The experiments indicated that "states" at 130 and 214 keV were complex, the former consisting of two major components having a separation of ~ 25 keV. Where the 348- and 420-keV and the 620- and 719-keV states were not fully resolved, a collective cross section for an average "state" at ~ 360 keV and at ~ 655 keV was determined. The measured inelastic excitation cross sections for the above states in platinum are shown in Fig. 10 and listed in Table VI. Figure 11 compares the observed excited structure of platinum with that reported in Ref. 21.

The errors in excitation cross sections given in Figs. 6, 8, and 10 and Tables IV-VI are "best judgments" of the standard deviations of the quantities, inclusive of estimated uncertainties in the "standard" elastic scattering cross sections of carbon.³ The determination of such errors was, of necessity, a subjective matter since the evaluation

of the primary experimental information required appreciable judgment, particularly with regards to the effect of experimental resolution.

Fig. 10

Inelastic Excitation Cross Sections of Platinum. Crosses indicate the experimental results for the reaction Q values (in MeV). The solid curves are representative of calculation (see Sec. IV); dashed curves are "eye guides."

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Fig. 11. A Comparison of the Structure of Platinum Derived from This Work with That Reported in Ref. 21.

C. Total Neutron Cross Sections

A cursory inspection of the preliminary results of this work and of the reported total cross sections and total scattering cross sections indicated a disagreement with the published total cross sections of tantalum.³² Only limited pertinent rhenium total-cross-section information was found in Ref. 32. These conflicting and/or sparse experimental results stimulated the present investigation of total neutron cross sections of rhenium and tantalum. The results are shown in Fig. 12 and listed in Tables VII and VIII. The experimental energy resolutions were ~ 2 keV (tantalum) and ~ 5 keV (rhenium). The statistical standard deviations of the cross sections were 1 to 3%. During the measurements, the fidelity of the apparatus was verified by determining the well-established total neutron cross section of carbon.³³

Fig. 12

The Total Cross Sections of Tantalum and Rhenium. The data points represent the measured values. The σ_{el} curves were obtained from the present work. The total scattering curve was taken from Langsdorf *et al.*³

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IV. DISCUSSION

A. Experimental Comparisons

The tantalum elastic scattering results obtained in the present work can be compared with previously reported^{4,9,12} experimental values at incident energies of ~ 1.0 MeV as shown in Fig. 13. The agreement between measured values is good, except near 90° , where the present work results in smaller cross sections than previously reported. This discrepancy cannot be explained by differing scattered neutron resolutions. Variations in the measured values near 90° should be particularly evident for the P_2 and P_4 terms of the Legendre expansions of the angular distributions. This is not evident in Fig. 14, where the present results for tantalum and platinum are compared with the total neutron-scattering distributions of Langsdorf *et al.*³ Particularly in the case of tantalum near 1.0 MeV the Langsdorf results, when corrected for inelastic scattering, yield ω_2

coefficients essentially identical to those obtained in the elastic scattering studies in this work. A similar agreement was found in the ω_4 coefficients. The directly measured total cross sections of tantalum as determined in this work (Fig. 12) are similar to the total scattering cross section reported by Langsdorf *et al.* For both tantalum and platinum the total scattering obtained by summing the present elastic and inelastic results differs by only a few percent from the Langsdorf values. Neither the total cross sections and the total scattering cross sections of tantalum and platinum obtained in this work nor the results of Langsdorf *et al.* agree with the total cross sections given in BNL-325.³² (See Figs. 12 and 14.) The measured total cross sections and scattering cross sections of rhenium determined in this work are consistent. Previously reported rhenium values are far too fragmentary to permit a reasonable quantitative comparison with past work.

Fig. 13

Differential Elastic Scattering Cross Section of Tantalum at ~ 1.0 MeV. Solid data points indicate cross sections obtained in this work; triangles indicate results of Ref. 42, squares of Ref. 4 and diamonds of Ref. 9. The curve is a fit of Eq. 1 to the data of the present experiment.

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Fig. 14. Comparison of Elastic Scattering from Tantalum and Platinum Obtained in This Work with the Total Scattering Results of Langsdorf *et al.*³ Dashed lines indicate the total scattering cross sections derived from the present work and the results of correcting the ω coefficients of Langsdorf *et al.* for inelastic scattering contributions to permit a comparison with the present elastic scattering distributions. The total cross sections given in BNL-325 are also indicated.³²

A few direct measurements of inelastic scattering from tantalum have been reported. Preliminary studies⁵ by the present authors are in substantial agreement with the results given here. There are only minor differences between the past and the present work near an excitation energy of $\overline{950}$ keV, where the later detailed results did not confirm a doublet structure initially reported.* Garber and Shrader⁸ measured the differential cross sections for the excitation of the $\overline{144}$ - and $\overline{313}$ -keV states at an incident neutron energy of ~ 700 keV. Their results were somewhat higher than those given here. This could have been due to multiple-scattering effects for which they made no corrections. Inelastic scattering from tantalum has been studied using threshold detectors.³⁴ The results were sensitive to the setting of the detector threshold in the context of the complex inelastically scattered neutron spectrum. Perhaps for this reason the threshold-detector results are in only fair agreement with those obtained in the present work.

Results of a number of studies of the $(n;n'\gamma)$ processes in tantalum, rhenium, and platinum have been reported.^{7,10,11,35} Measurements of this type are not always easy to evaluate in terms of inelastic scattering cross sections since the interpretation can depend upon a quantitative knowledge of internal conversion, branching ratios, angular distributions, and experimental factors such as gamma-ray absorption within the samples. Thus it is not unexpected that inelastic scattering cross sections deduced from $(n;n'\gamma)$ measurements with tantalum, rhenium, and platinum at incident neutron energies of 500 keV and below are not always in qualitative agreement with the results of the present work. At higher incident neutron energies, Lind and Day¹¹ reported cross sections for the production of 480-keV gamma rays similar in magnitude to the excitation cross sections of the 506-keV state of tantalum given here. Unfortunately, the same authors find a cross section for gamma-ray production resulting from the inelastic excitation of the $\overline{313}$ -keV state in tantalum appreciably smaller than that indicated by the present work.

B. Comparison with Calculation and Structure Systematics

The elements tantalum, rhenium, and platinum, are primarily constituted of the isotopes Ta¹⁸¹ (99%); Re¹⁸⁵ (37%), Re¹⁸⁷ (63%); Pt¹⁹⁴ (33%), Pt¹⁹⁵ (34%), Pt¹⁹⁶ (25%), and Pt¹⁹⁸ (7%). Scattering from these elements is complex because of the isotopic mixture and/or the complicated nuclear structure. These factors make it difficult to calculate elastic and inelastic neutron-scattering probabilities and form reasonable comparisons with experiment. The calculational procedure followed here consisted of an initial search for an optical potential reasonably describing the observed elastic neutron scattering inclusive of compound-nuclear contributions, assuming the low-energy excited structure reported in the literature was

* Here and in subsequent portions of this report a superscript bar on an energy value denotes a quantity as observed in the present experiments.

valid. The search was restricted to the following spherical, local, nonenergy-dependent, and surface-absorption optical potential suggested by Moldauer:^{36,38}

$$\left. \begin{aligned} -Vq - iWp + V_{s0} \left(\frac{\hbar}{\mu_{\pi} c} \right)^2 \frac{\sigma \cdot \ell}{r} \frac{dq}{dr}, \\ q(r) = \left[1 + \exp\left(\frac{r-R}{a}\right) \right]^{-1}, \\ p(r) = \exp\left(-\frac{r-R-c}{b}\right), \end{aligned} \right\} \quad (2)$$

and

$$R = r_0 A^{1/3} + r_1,$$

where

$$r_0 = 1.16 \text{ F},$$

$$r_1 = 0.6 \text{ F},$$

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

and

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

The potential of Eq. 2 is generally applicable to neutron-scattering calculations at incident neutron energies of $\lesssim 2$ MeV, and it forms a convenient spherical approximation from which to attempt a description of the results of these experiments.³⁶ The spherical potential of Eq. 2 is not strictly applicable to the deformed nuclei tantalum, rhenium, and platinum and can provide no insight into the direct interaction between the neutron and collective nuclear configurations. Such direct reaction processes are probably not large at the energies of these experiments, as indicated by the near isotropy of most of the observed inelastic scattering angular distributions.

Elastic neutron-scattering angular distributions were calculated at incident energy intervals of $\lesssim 0.2$ MeV from 0.2 to 1.6 MeV using a pre-determined matrix of V and W values extending over the intervals $40 \leq V \leq 50$ Mev, $2 \leq W \leq 20$ MeV.³⁷ From this V - W space, a region yielding a "good" description of the measured elastic scattering results was selected for more detailed calculation and the selection of the "best" V and W values. This selection was primarily subjective, but in some instances was based upon a minimum χ^2 fit to the measured angular distributions. Chi-square fitting of all the measured elastic distributions was not economically feasible, and averaging of experimental values before such fitting would remain in a subjective procedure. After the above

procedures, resonance-width fluctuation corrections were applied following the method of Moldauer.^{37,38} Generally, these corrections did not appreciably alter the initial results (see Fig. 5 for example).

After the measured elastic scattering had been described satisfactorily, the inelastic scattering cross sections were calculated using the Hauser-Feshbach formula.³⁸⁻⁴⁰ The excited structure reported in the literature was modified with respect to energies, spins, and parities, and additions or deletions made to obtain a reasonable description of the experimental results. These modifications were guided by, and related to, the theoretical understanding of excited states in deformed nuclei, and the comparison of calculation and experiment provided an insight into the nature of this structure.^{2,41}

The results obtained using the above procedures are outlined below by element. They are most detailed for the monoisotopic element, tantalum, and become progressively less definitive for the more isotopically complex elements, rhenium and then platinum.

1. Tantalum

$^{181}_{73}\text{Ta}$ has been extensively studied using Coulomb excitation methods and observing the radioactive decay of both Hf^{181} and W^{181} .²¹ The low-energy excited structure is attributed to single-particle states and their associated rotational bands.⁴¹ Vibrational states are apparently not contributing factors at excitation energies available in the present experiments. The single-particle structure is described by the calculations of Mottelson and Nilsson.² Assuming a deformation of $\delta \sim 0.3$, these calculations attribute to the 73rd proton a $9/2^-$ [514] or $5/2^+$ [402] state. However, the $7/2^+$ [404] state is energetically similar to the $9/2^-$ [514] state, and the pairing energy can result in a ground state of $7/2^+$ [404] in accord with observation.²¹ The first excited state is then $9/2^+$ [514] and is identified with the ~ 6 -keV state not resolved in the present experiments. The next single-particle state should then be $5/2^+$ [404] and is reported at an energy of 482 keV. A $1/2^+$ [411] state with a $(1/2^+)(7/2^+)^2(9/2^-)^2$ single-particle configuration is reported at an energy of 615 keV. As shown in Fig. 7, the above single-particle states appear to have associated rotational bands.

Initial elastic scattering calculations were made with b , the surface absorption, held constant at 0.5 F, and V and W varying. The calculated results were not particularly descriptive of either the measured total elastic scattering cross sections, the total cross sections, or the observed elastic angular distributions as indicated in Figs. 15 and 16. Small real potentials ($V \sim 42$ MeV) resulted in inelastic cross sections in fair agreement with observed values (Fig. 17), but were particularly poor in describing the experimental elastic scattering cross sections (Fig. 15, for example). To

112-8146

Fig. 15

Comparison of Calculated and Measured Elastic Scattering from Tantalum. The potential of Eq. 2 was employed with $b \equiv 0.5$ F, and both the real (V) and imaginary (W) portions of the potential allowed to vary with the results indicated by the respective curves.

112-8259

Fig. 17

A Comparison of Measured and Calculated Inelastic Excitation Cross Sections of Tantalum. The respective reaction Q values are noted in MeV. The curves correspond to the results obtained with various choices of the real (V) and imaginary (W) potential of Eq. 2, all with the surface absorption width $b = 0.5$ F.

112-8222 Rev. 1

Fig. 16

Comparison of Selected Experimental and Calculated Elastic Scattering Angular Distributions of Tantalum. Distributions obtained with real potentials of $V = 50$, 42, and 46 MeV are indicated. Unless otherwise specified by an "arrow" notation, the imaginary potential (W) was 14 MeV. In all cases, the Gaussian surface-absorption width of Eq. 2 was 0.5 F.

112-8205

Fig. 18. Experimental Elastic Angular Distributions for Tantalum Compared with the Results of Calculations Based upon the "Best" Choice of Potential Parameters Indicated by the Solid Curves. The dotted lines are "eye guides" through the experimental points, and the dashed lines are the calculated results given in Ref. 20.

improve the description of scattering from tantalum, we made the Gaussian surface-absorption width of the potential of Eq. 2, in addition to V and W , a variable. In this manner, a reasonable agreement with experiment was achieved with $V = 46$ MeV, $W = 14$ MeV, and $b = 1.25$ F. These calculated results are indicated by the solid curves in Figs. 3 and 18 and are in reasonable agreement with the experimental elastic scattering cross sections, total neutron cross sections, and, at incident neutron energies of ≤ 1.2 MeV, the elastic angular distributions. The potential of Eq. 2 with these parameters was judged a reasonable "spherical" approximation for calculating neutron scattering from the deformed nucleus tantalum and resulted in a better agreement with experiment than obtained with some other spherical potentials²⁰ (see Fig. 18). The potential differs from that generally proposed by Moldauer³⁶ only in the Gaussian absorption width of 1.25 F as compared to the value of 0.5 F found applicable to lighter and spherical nuclei. It is tempting to associate this difference with the large deformation of Ta^{181} .

Using level structure reported in Ref. 21 (see Fig. 5) and the above potential, we calculated the inelastic excitation cross sections of tantalum with results indicated by the solid curves of Fig. 4. The calculated excitation of the unresolved $9/2^-$ state at ~ 6 keV was large and was included with the elastic component in making comparisons with measured elastic scattering. The calculated cross section for the excitation of the observed composite 144 -keV state ($11/2^-$, $9/2^+$) was similar to the measured value, and, indeed, the calculated ratio of the excitation of the $9/2^+$ to that of the $11/2^-$ state was ~ 1.9 , qualitatively in agreement with the experimental estimate of ~ 1.6 . Calculated values were

slightly lower than the experimental excitation of both the $\overline{313}$ -keV ($11/2+$) state and the $\overline{506}$ -keV ($13/2+$, $5/2+$) state. Calculated cross sections for the excitation of the $\overline{620}$ -keV ($1/2+$, $3/2+$) and the $\overline{720}$ -keV ($15/2+$, $3/2+$) states were appreciably lower than the experimental values. Uncertain assignments of ($11/2+$, $7/2+$) were used in calculating the excitation of the $\overline{930}$ -keV state, and, as a result, the computed values are speculative.

The differences between the calculated and observed excitations of the $\overline{620}$ - and $\overline{720}$ -keV states could have been attributed to uncertainty and/or incompleteness in the pertinent reported structure employed in the calculations. As an alternative to the published structure, a single particle-rotational MODEL (left of Fig. 7) was constructed from the predictions of Mottelson and Nilsson and the energetics of the observed low-energy structure, retaining only such states as could be excited by neutrons of $\ell \lesssim 4$.^{2,41} The first two rotational sequences of the MODEL, based upon [404] and [514] configurations, were well established from a number of measurements.²¹ Only the initial states ($5/2+$ [402] and $1/2+$ [411]) of the two subsequent sequences were experimentally defined.²¹ It was assumed that the reported states at 619 and 699 keV were $7/2+$ [402] and $3/2+$ [411], respectively, and the second members of the rotational sequences. With this premise, the remaining structure of the MODEL, shown in Fig. 7, followed. The energetics of the simple MODEL were not expected to agree accurately with experiment as no cognizance was taken of perturbing effects such as coriolis mixing of internal motions and rotations, but the MODEL did form a qualitative basis for the calculation and the assay of excited structure.

The dashed curves of Fig. 6 indicated results of calculations carried out using the MODEL. These results are in better agreement with experiment than those obtained using the reported structure (solid curves of Fig. 6), particularly for excitations in the range 600 to 800 keV. This improved agreement is principally due to the [402] and [411] sequences of the MODEL, which are consistent with previously reported structure information with the exception of log ft values obtained from studies of a weak beta-ray transition ($\sim 4\%$) from Hf^{181} .²¹ The instrumental resolution and available energy range of the present experiments were not sufficient to permit a more critical assay of the MODEL or alternative structure concepts. However, results of the present experiment and calculations based upon the reported structure were clearly inconsistent, indicating that the reported structure of tantalum should be revised.

2. Rhenium

The procedures outlined above were employed to calculate the elastic and inelastic neutron-scattering cross sections of rhenium. The initial computations used the level structure of Re^{185} and Re^{187} reported in Ref. 21 (Fig. 9) and the potential of Eq. 2. The surface-absorption width was fixed at $b = 0.5 F$, and V and W varied to obtain the "best" description

of experiment. Figure 4 compares results of calculations employing a real potential, $V = 46$ MeV, and imaginary potentials, $2 \leq W \leq 18$ MeV, with measured elastic scattering cross sections. Parameter values $V = 46$ MeV and $W = 14$ MeV were judged to provide the best description of elastic scattering and total neutron cross sections of rhenium. A value of $b = 1.25$ F, as selected for tantalum above, resulted in poor agreement with experiment at incident neutron energies of $\lesssim 700$ keV. The difference in the potential surface absorption width selected for tantalum and for rhenium may reflect the smaller distortion of rhenium ($\delta \sim 0.2$) as compared to tantalum ($\delta \sim 0.3$).¹

The low-energy excited structure of the 185 and 187 isotopes of rhenium can be described in terms of single-particle and associated rotational states with γ -vibrational states at excitation energies above ~ 600 keV.^{2,21,41} Assuming strong pairing, the unified mode predicts a ground state of $5/2^+ [402]$ with the particle configuration $(7/2^+)^2 (5/2^+ (9/2^-)^2$, in accord with observation.^{2,21} The next single-particle configuration is $(7/2^+)^2 (5/2^+)^2 (9/2^-)$, corresponding to the reported $9/2^- [514]$ states in Re^{187} at 206 keV and observed as a $\overline{219}$ -keV state in the present experiments. The first and second excited states in the ground-state rotational sequence of both rhenium isotopes ($7/2^+$, $9/2^+$) have been observed in Coulomb excitation experiments and were evident as states at $\overline{132}$ and $\overline{313}$ keV in the present work.^{21,22} The theoretically predicted $9/2^-$ single-particle state in Re^{185} presents an enigma. It has not been reported in Coulomb excitation studies (which would not have been sensitive to its presence), yet its analog is evident in Re^{183} (496 keV) and Re^{187} (209 keV).²¹ The state in rhenium observed in the present work at $\overline{386}$ keV energetically corresponds to the predicted and heretofore missing $9/2^-$ single-particle state in Re^{185} .

Above excitation energies of ~ 500 keV, the structures in Re^{185} and Re^{187} are complex and uncertain, and the resolution of the present work limits the experimental information. The $\overline{518}$ -keV state observed in the present work was attributed to the reported $1/2^+$ (511-keV) state in Re^{187} ; the $\overline{637}$ -keV state to a composite of $1/2^+$ and $3/2^+$ states in both isotopes; the $\overline{767}$ -keV state to $3/2^+$ (Re^{185}) and $5/2^-$ (Re^{187}) states; and the $\overline{865}$ -keV state to a complex of levels in both isotopes. The structure origin of observed states at $\overline{963}$, $\overline{1060}$, and $\overline{1135}$ keV remained obscure.

The inelastic excitation cross sections of rhenium were calculated using the above "best" potential and the reported excited structure (Fig. 9) with the addition of a $9/2^-$ state at $\overline{387}$ keV in the Re^{185} isotope. The calculated results, indicated by the solid curves in Fig. 8, reasonably described the excitation of states at energies of $\lesssim 500$ keV. However, the agreement with experiment deteriorated as the excitation energy extended above 500 keV. The discrepancy between the calculated and measured excitation of the states at $\overline{767}$, $\overline{518}$, and $\overline{637}$ keV cast doubt on the validity

and/or completeness of the reported structure in this energy region. The inversion of the parities of the $9/2$ states on Re^{185} was considered. The results of calculations assuming assignments $9/2+$ (387 keV) and $9/2-$ (286 keV) did not significantly improve the agreement with experiment, as is shown by the dashed curves in Fig. 6, nor was such an inversion compatible with the results of a number of Coulomb excitation experiments.^{21,22} We thus concluded that the 387-keV state observed in the present experiments was probably the predicted $9/2-$ [514] single-particle state in Re^{185} .^{2,41}

3. Platinum

Platinum was the most isotopically complex of the elements studied, and the computation of cross sections would have been extensive if carried out by isotope. To avoid these complexities, the present calculations were based upon a simplified MODEL element consisting of Pt^{194} (66%) and Pt^{195} (34%). This MODEL reasonably described rotational ($K = 0$) and the γ -vibrational states ($K = 2$) of the even isotopes of platinum in the energy range of interest and accurately represented the odd isotope of the element Pt^{195} . Using this MODEL, the published structure of Pt^{194} and Pt^{195} , and the potential of Eq. 2 a good description of elastic scattering was obtained with a real potential magnitude $V = 46$ MeV, an imaginary potential $W = 14$ MeV, and an absorption width of $b = 0.5$ F, as indicated by the solid curves in Fig. 5.²¹ The agreement between calculation and experiment was better than that obtained for either rhenium or tantalum, possibly as a result of the relatively small deformation of platinum ($\delta \sim 0.15$).¹ The effect of resonance-width fluctuations was assayed and found small, as indicated by the dashed lines of Fig. 5, which represent the calculated results, including fluctuation corrections.

At excitation energies above ~ 800 keV, the platinum MODEL becomes an inferior approximation of the actual structure, and the measurements were less than definitive. The observed states at 130 and 214 keV were attributed to the excitation of pairs and triplets of states in Pt^{195} , as evident in Fig. 11. The observed 348-keV state was believed a composite of contributions from $2+$ states in the even isotopes, and the 420-keV state was attributed entirely to a 420-keV $5/2+$ level in Pt^{195} . No quantitative correlation with reported structure was attempted at excitations above ~ 600 keV. Qualitatively, the observed states at 620 and 719 keV are attributed to $2+$ γ -vibration states in the even isotopes and a $7/2+$ state in Pt^{195} .

The inelastic excitation cross sections were calculated using the above potential and MODEL with the results indicated by the solid curves of Fig. 10. The agreement between calculation and experiment was reasonable at excitation energies where the MODEL was a suitable approximation of the complex structure of the natural element.

V. SUMMARY

The present experiments extended the knowledge of elastic and inelastic neutron scattering and total cross sections of tantalum, rhenium, and platinum at incident neutron energies of $\lesssim 1.5$ MeV. The measured results were reasonably described by calculations based upon a local, energy-independent optical potential and the theory of average compound-nucleus cross sections. The calculations demonstrated the applicability of a well-chosen spherical, surface-absorption, optical potential for the interpolation and extrapolation of measured scattering cross sections over a region of large and rapidly changing deformation. Comparison with experiment indicated a proportionality between the strength of the surface absorption and the degree of deformation. Resonance-width fluctuation effects were found to be small. Uncertainties in calculated inelastic scattering cross sections, particularly at excitations $\gtrsim 500$ keV, tended to be more the result of inadequate knowledge of excited nuclear structure than of deficiencies in the potential employed.

The derivation of structure information from the measurements was restricted by experimental resolutions and sensitivities and by the isotopic complexity of the natural elements employed in the work. Despite these restrictions, the experiments indicated that there were omissions and/or inappropriate spin and parity assignments in the reported low-energy excited structure of both tantalum and rhenium. Revisions of the excited structure of tantalum consistent with the unified model and experimental observation were proposed. Modifications of, and additions to, the reported structure of rhenium were indicated by the experimental results, inclusive of a specific state attributed to the predicted single-particle configuration in Re^{185} .

APPENDIX
Tabular Results

TABLE I. Differential Elastic Scattering Cross Sections of Tantalum in the Format of Eq. 1

E(MEV)	SIG.R	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.300	6.460	.717	.042	.450	.052	.221	.085	.210	.085	.011	.118
.300	6.480	.729	.017	.520	.020	.223	.038	.171	.031	.070	.048
.350	6.830	.826	.046	.436	.059	.157	.098	.137	.105	-.032	.039
.353	6.720	.843	.040	.462	.047	.151	.093	.082	.088	-.043	.053
.355	6.640	.845	.035	.452	.033	.141	.095	.095	.071	-.065	.079
.371	6.750	.830	.022	.482	.029	.083	.041	.029	.049	-.018	.032
.377	6.810	.818	.022	.428	.031	.034	.041	-.011	.052	.012	.018
.393	6.690	.804	.029	.484	.038	.153	.057	.010	.063	.008	.066
.406	6.760	.843	.043	.506	.055	.155	.083	-.033	.090	.051	.104
.410	6.990	.865	.036	.540	.046	.141	.068	-.006	.076	.076	.075
.430	6.680	.823	.029	.513	.036	.142	.057	.032	.060	.140	.082
.450	6.540	.817	.023	.521	.031	.173	.044	.033	.052	.053	.037
.455	6.560	.821	.032	.537	.044	.180	.061	.014	.073	.017	.049
.471	6.740	.891	.024	.609	.031	.246	.047	.099	.052	.081	.054
.477	6.740	.926	.019	.621	.025	.244	.036	.102	.042	.105	.033
.495	6.830	.888	.023	.667	.030	.252	.046	.097	.049	.053	.059
.508	6.700	.895	.024	.682	.033	.220	.046	.069	.053	-.017	.044
.510	6.700	.878	.027	.682	.038	.210	.052	.073	.060	-.032	.047
.513	6.580	.878	.026	.649	.035	.191	.050	.063	.059	-.032	.043
.530	6.440	.933	.028	.693	.038	.241	.053	.061	.063	-.017	.046
.533	6.370	.917	.026	.673	.034	.231	.051	.049	.056	-.022	.062
.543	6.240	.938	.026	.701	.035	.272	.050	.067	.059	.007	.046
.545	6.300	.958	.015	.711	.022	.253	.027	.045	.038	.000	.000
.550	6.090	.899	.017	.676	.025	.248	.031	.052	.043	.000	.000
.577	6.270	1.019	.021	.789	.029	.292	.038	.049	.049	-.009	.017
.593	5.960	1.034	.034	.814	.054	.326	.061	.091	.062	.050	.073
.606	5.750	1.053	.035	.822	.055	.322	.063	.067	.065	.067	.076
.610	5.740	1.064	.023	.790	.028	.320	.045	.058	.047	.050	.065
.628	5.770	1.092	.012	.890	.016	.343	.023	.078	.026	.023	.026
.632	5.930	1.109	.010	.939	.014	.367	.020	.120	.024	.019	.017
.650	5.630	1.163	.032	.932	.028	.376	.040	.093	.042	.024	.051

TABLE I (Contd.)

E(MEV)	SIG.8	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.660	5.620	1.161	.029	.923	.037	.325	.048	.082	.053	.012	.046
.670	5.540	1.162	.023	.955	.042	.368	.059	.119	.066	.033	.069
.675	5.600	1.169	.022	.945	.047	.375	.064	.120	.073	.058	.069
.690	5.520	1.241	.029	1.047	.036	.527	.057	.163	.060	.116	.082
.713	5.380	1.200	.023	1.031	.026	.430	.044	.166	.058	.038	.055
.720	5.370	1.167	.027	.997	.029	.377	.051	.163	.070	.000	.059
.720	5.160	1.205	.025	1.106	.031	.487	.048	.222	.051	.000	.069
.755	5.230	1.197	.030	1.128	.038	.513	.060	.193	.063	.051	.086
.767	5.340	1.219	.048	1.152	.059	.501	.094	.153	.098	.045	.134
.775	5.660	1.235	.039	1.150	.048	.507	.076	.105	.079	.038	.108
.800	5.600	1.217	.015	1.088	.019	.465	.029	.096	.031	.031	.042
.825	5.340	1.238	.029	1.195	.037	.548	.058	.178	.061	.094	.083
.860	5.310	1.305	.025	1.253	.066	.607	.087	.185	.086	.044	.065
.872	5.220	1.272	.031	1.218	.074	.603	.099	.139	.099	.054	.082
.875	5.340	1.215	.023	1.232	.029	.690	.045	.164	.048	.058	.065
.900	5.160	1.265	.014	1.312	.018	.596	.028	.108	.030	.075	.041
.932	5.000	1.286	.017	1.348	.021	.739	.034	.169	.035	.072	.048
.950	5.110	1.256	.027	1.283	.033	.665	.053	.141	.056	.030	.076
.955	5.220	1.274	.034	1.305	.042	.698	.067	.188	.071	.034	.096
.971	5.270	1.263	.022	1.338	.027	.763	.043	.193	.045	.098	.062
.977	5.250	1.275	.020	1.404	.026	.837	.040	.261	.042	.123	.058
.995	5.020	1.285	.021	1.365	.026	.814	.041	.196	.044	.082	.060
1.008	5.000	1.302	.028	1.340	.036	.773	.057	.165	.060	.022	.081
1.010	4.990	1.301	.021	1.321	.026	.773	.042	.156	.044	.037	.060
1.013	5.030	1.276	.026	1.298	.032	.746	.051	.111	.054	.041	.074
1.026	4.900	1.329	.037	1.298	.046	.757	.073	.173	.077	.009	.105
1.030	4.920	1.319	.036	1.294	.045	.773	.071	.171	.075	.037	.102
1.050	4.960	1.288	.045	1.316	.058	.795	.087	.219	.096	.009	.110
1.055	5.090	1.247	.042	1.331	.055	.781	.081	.209	.091	.038	.093
1.070	5.260	1.317	.057	1.335	.071	.858	.112	.170	.117	.094	.160
1.093	5.030	1.422	.029	1.398	.036	.889	.058	.224	.060	.086	.082

TABLE I (Contd.)

E(MEV)	SIG.σ	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
1.106	4.710	1.462	.025	1.425	.031	.889	.050	.261	.052	.038	.071
1.110	4.620	1.465	.027	1.419	.033	.882	.053	.248	.055	.066	.075
1.128	4.730	1.474	.029	1.467	.039	.957	.054	.333	.064	.045	.046
1.132	4.910	1.464	.026	1.476	.036	.940	.046	.332	.060	.007	.018
1.150	4.870	1.436	.014	1.482	.019	1.011	.027	.407	.031	.091	.043
1.153	4.850	1.437	.015	1.517	.020	1.065	.028	.451	.033	.116	.045
1.155	5.010	1.472	.010	1.527	.012	1.023	.019	.410	.020	.093	.027
1.171	5.080	1.432	.038	1.493	.048	.911	.075	.333	.079	.060	.108
1.177	5.140	1.460	.050	1.517	.062	.915	.097	.308	.103	.104	.140
1.193	5.010	1.429	.044	1.492	.058	.996	.084	.301	.097	.050	.084
1.206	5.010	1.468	.040	1.524	.053	1.054	.076	.291	.088	.023	.073
1.210	5.080	1.446	.039	1.507	.048	1.017	.076	.285	.080	.034	.109
1.227	4.920	1.499	.030	1.560	.037	1.101	.059	.307	.062	.076	.085
1.230	4.890	1.504	.026	1.573	.032	1.133	.051	.335	.054	.073	.073
1.232	4.840	1.465	.022	1.522	.027	1.038	.044	.263	.046	.023	.062
1.250	4.750	1.516	.040	1.602	.055	1.133	.075	.352	.092	.021	.047
1.252	4.700	1.545	.043	1.641	.061	1.177	.081	.382	.101	.041	.043
1.252	4.730	1.510	.053	1.604	.074	1.143	.098	.382	.123	.005	.050
1.253	4.790	1.507	.053	1.598	.073	1.166	.100	.449	.122	.007	.066
1.255	5.010	1.488	.036	1.546	.044	1.025	.070	.246	.073	.011	.100
1.272	4.740	1.495	.023	1.557	.030	1.052	.044	.221	.050	.037	.048
1.276	4.700	1.514	.027	1.596	.036	1.130	.052	.268	.060	.078	.055
1.277	4.720	1.503	.029	1.571	.036	1.116	.057	.244	.061	.117	.083
1.290	4.700	1.546	.025	1.603	.031	1.119	.049	.252	.052	.169	.071
1.300	4.640	1.538	.013	1.708	.016	1.209	.025	.325	.027	.209	.037
1.332	4.440	1.593	.023	1.762	.029	1.217	.045	.368	.047	.188	.065
1.350	4.530	1.574	.033	1.743	.043	1.217	.064	.418	.070	.109	.096
1.353	4.570	1.577	.033	1.748	.044	1.251	.064	.443	.072	.091	.098
1.355	4.810	1.618	.037	1.809	.047	1.178	.074	.323	.078	.037	.106
1.367	4.870	1.627	.050	1.800	.062	1.092	.098	.269	.103	.039	.140
1.375	4.970	1.714	.042	1.780	.052	1.184	.082	.311	.086	.081	.118
1.400	4.580	1.727	.026	1.807	.032	1.242	.051	.328	.054	.127	.073
1.450	4.500	1.879	.013	1.895	.016	1.350	.025	.286	.026	.033	.036
1.475	4.720	1.856	.082	1.918	.102	1.458	.160	.426	.169	.397	.230

TABLE II. Differential Elastic Scattering Cross Sections of Rhenium in the Format of Eq. 1

E(MEV)	SIG,R	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.300	5.900	.706	.015	.461	.022	.194	.027	.065	.037	.000	.000
.322	5.370	.682	.048	.412	.066	.180	.088	.047	.109	.022	.056
.325	5.270	.675	.040	.297	.050	.144	.077	.051	.082	.045	.113
.345	5.800	.589	.046	.359	.068	.100	.081	.076	.111	.000	.000
.355	5.900	.688	.045	.439	.064	.140	.082	.184	.105	.116	.037
.360	5.890	.788	.026	.471	.033	.192	.051	.247	.054	.233	.074
.377	5.550	.655	.056	.467	.074	.088	.106	.001	.123	.006	.103
.380	5.380	.584	.074	.533	.092	.001	.144	.070	.152	.012	.206
.400	5.480	.698	.038	.521	.052	.121	.070	.013	.085	.026	.048
.400	5.310	.647	.035	.500	.043	.096	.068	.086	.071	.053	.097
.420	5.640	.733	.046	.511	.057	.104	.090	.010	.095	.108	.130
.445	5.270	.697	.021	.498	.030	.047	.040	.033	.050	.039	.018
.455	5.390	.701	.027	.577	.037	.174	.052	.040	.063	.057	.035
.460	5.510	.744	.025	.677	.031	.291	.050	.163	.052	.114	.071
.476	5.270	.814	.021	.679	.029	.257	.041	.071	.047	.095	.042
.477	5.130	.806	.022	.669	.028	.280	.044	.098	.047	.143	.064
.480	5.420	.777	.031	.694	.039	.329	.061	.111	.064	.245	.087
.500	5.580	.834	.014	.781	.021	.275	.025	.072	.035	.000	.000
.520	5.400	.790	.009	.751	.012	.244	.018	.067	.020	.012	.020
.520	5.200	.750	.015	.692	.018	.211	.029	.078	.030	.024	.041
.543	5.170	.811	.026	.754	.037	.267	.047	.046	.062	.003	.014
.545	5.050	.781	.019	.719	.026	.273	.036	.061	.044	.005	.022
.550	5.140	.770	.023	.742	.034	.246	.041	.071	.057	.000	.000
.577	5.140	.921	.019	.867	.026	.367	.034	.039	.043	.037	.020
.580	5.000	.938	.014	.861	.018	.426	.028	.079	.030	.074	.041
.600	4.860	.977	.016	.861	.020	.401	.032	.094	.034	.060	.046
.620	4.460	.935	.013	.878	.017	.347	.027	.036	.028	.037	.038
.640	4.330	1.033	.018	1.002	.022	.426	.035	.153	.037	.021	.051
.660	4.410	1.059	.012	1.000	.015	.389	.023	.066	.024	.007	.033
.677	4.310	1.079	.025	1.041	.032	.551	.049	.180	.052	.105	.071
.680	4.560	1.101	.020	1.059	.025	.579	.039	.170	.041	.094	.056

TABLE II (Contd.)

E (MEV)	SIG. B	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.700	4.320	1.165	.026	1.131	.032	.565	.051	.213	.053	.110	.073
.723	4.110	1.095	.020	1.221	.026	.593	.037	.217	.040	.037	.049
.725	4.090	1.114	.019	1.217	.026	.641	.035	.223	.038	.115	.044
.725	4.070	1.085	.027	1.310	.038	.734	.048	.265	.053	.222	.055
.740	3.970	1.186	.007	1.201	.009	.661	.014	.212	.015	.093	.020
.760	4.090	1.133	.009	1.266	.011	.605	.018	.238	.019	.049	.026
.775	4.300	1.160	.018	1.210	.025	.583	.033	.128	.042	.037	.014
.775	4.070	1.191	.010	1.189	.012	.558	.019	.101	.020	.074	.028
.800	3.990	1.162	.019	1.269	.025	.650	.036	.207	.042	.019	.032
.800	3.670	1.171	.023	1.276	.028	.643	.045	.187	.047	.038	.064
.825	3.940	1.181	.024	1.303	.033	.666	.045	.188	.055	.081	.035
.825	3.670	1.191	.025	1.259	.032	.566	.048	.168	.052	.163	.071
.845	4.020	1.226	.015	1.411	.020	.824	.029	.280	.034	.011	.029
.855	4.010	1.249	.013	1.415	.018	.847	.025	.331	.030	.060	.023
.860	3.590	1.268	.017	1.386	.021	.890	.033	.380	.035	.120	.047
.875	3.980	1.254	.013	1.321	.018	.760	.023	.210	.030	.039	.009
.875	3.730	1.347	.006	1.294	.008	.718	.012	.231	.013	.078	.018
.900	4.230	1.217	.016	1.442	.019	.870	.031	.262	.032	.047	.044
.925	4.090	1.244	.029	1.537	.037	1.012	.058	.356	.061	.033	.083
.950	4.150	1.262	.062	1.526	.077	.995	.121	.317	.127	.027	.173
.976	4.040	1.282	.036	1.508	.047	.989	.069	.298	.074	.106	.091
.977	4.100	1.218	.034	1.506	.042	.952	.066	.306	.070	.090	.095
.980	4.080	1.215	.012	1.448	.015	.997	.023	.292	.025	.282	.034
1.000	4.120	1.234	.041	1.482	.054	.988	.077	.224	.089	.054	.073
1.000	4.120	1.245	.039	1.453	.048	.997	.076	.204	.080	.082	.109
1.000	4.190	1.149	.060	1.356	.075	.923	.118	.065	.124	.067	.169
1.020	3.810	1.239	.043	1.476	.054	.927	.084	.210	.089	.007	.122
1.020	3.600	1.304	.048	1.508	.059	.888	.093	.253	.098	.061	.134
1.040	3.440	1.348	.047	1.468	.059	1.053	.092	.321	.097	.001	.132
1.060	3.780	1.317	.024	1.481	.032	.999	.046	.256	.052	.037	.050
1.060	3.720	1.317	.023	1.470	.031	.992	.044	.289	.051	.035	.038

TABLE II (Contd.)

E(MEV)	SIG,B	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
1.060	3.910	1.323	.020	1.501	.029	1.032	.034	.186	.047	.000	.000
1.080	3.790	1.371	.033	1.492	.041	1.203	.064	.389	.068	.236	.093
1.100	3.770	1.422	.022	1.584	.027	1.128	.043	.377	.045	.002	.062
1.100	3.640	1.396	.021	1.519	.026	1.046	.041	.308	.043	.041	.058
1.122	3.600	1.427	.048	1.594	.059	1.221	.094	.480	.098	.027	.134
1.120	3.310	1.338	.061	1.496	.076	1.178	.120	.487	.126	.002	.171
1.146	3.870	1.428	.027	1.580	.035	1.272	.053	.516	.059	.160	.080
1.153	3.920	1.434	.015	1.611	.020	1.273	.030	.527	.034	.100	.046
1.155	3.950	1.474	.015	1.625	.018	1.230	.029	.461	.031	.045	.042
1.160	3.790	1.382	.010	1.524	.012	1.097	.020	.364	.021	.030	.029
1.177	4.040	1.477	.036	1.588	.044	1.158	.070	.355	.073	.030	.100
1.180	3.910	1.355	.068	1.456	.084	1.031	.132	.297	.139	.127	.189
1.200	3.910	1.440	.063	1.621	.078	1.276	.123	.403	.129	.115	.176
1.200	3.940	1.518	.057	1.659	.070	1.342	.111	.449	.116	.131	.159
1.223	3.890	1.575	.038	1.709	.049	1.420	.074	.479	.082	.121	.089
1.225	4.010	1.582	.033	1.731	.043	1.425	.063	.505	.072	.069	.063
1.225	3.890	1.567	.021	1.717	.031	1.328	.038	.437	.052	.000	.000
1.245	3.790	1.568	.033	1.679	.041	1.375	.065	.374	.068	.148	.093
1.255	3.730	1.603	.041	1.759	.051	1.403	.080	.354	.084	.124	.115
1.260	3.550	1.527	.054	1.683	.067	1.258	.105	.272	.111	.035	.151
1.275	3.660	1.534	.026	1.650	.038	1.341	.046	.371	.063	.000	.000
1.300	3.770	1.624	.040	1.728	.058	1.331	.070	.435	.096	.000	.000
1.325	3.440	1.634	.024	1.738	.030	1.378	.048	.352	.050	.061	.069
1.345	3.740	1.664	.031	1.806	.038	1.431	.061	.423	.064	.191	.087
1.355	3.890	1.709	.047	1.918	.058	1.516	.092	.423	.096	.151	.131
1.360	4.000	1.640	.058	1.885	.072	1.400	.113	.265	.119	.007	.162
1.377	3.890	1.670	.030	1.815	.037	1.414	.059	.350	.061	.066	.084
1.380	3.750	1.620	.024	1.860	.029	1.350	.047	.320	.049	.060	.067
1.400	3.760	1.706	.030	1.843	.037	1.492	.059	.365	.062	.143	.085
1.400	3.800	1.710	.049	1.880	.061	1.580	.095	.343	.100	.205	.137
1.422	3.720	1.715	.064	1.800	.079	1.445	.125	.360	.131	.039	.178
1.425	3.550	1.750	.049	1.800	.061	1.540	.096	.430	.101	.007	.137
1.450	3.530	1.701	.031	1.812	.046	1.652	.056	.489	.073	.252	.099
1.450	3.590	1.800	.003	1.820	.004	1.450	.006	.460	.006	.034	.009
1.475	3.810	1.850	.021	1.950	.026	1.660	.040	.505	.043	.360	.058
1.500	3.940	1.760	.058	1.800	.072	1.360	.113	.300	.119	.088	.162

TABLE III. Differential Elastic Scattering Cross Sections of Platinum in the Format of Eq. 1

E (MEV)	SIG.R	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.300	7.280	.529	.035	.380	.051	.145	.063	.070	.077	.021	.041
.300	7.600	.442	.041	.284	.059	.083	.076	.071	.085	.042	.082
.322	7.080	.483	.039	.294	.057	.163	.068	.164	.093	.000	.000
.325	7.180	.529	.061	.355	.089	.148	.106	.197	.146	.000	.000
.345	6.870	.575	.016	.375	.024	.123	.030	.107	.040	.000	.000
.355	6.700	.658	.008	.474	.011	.174	.016	.119	.018	.001	.016
.360	6.650	.734	.011	.574	.014	.228	.022	.133	.023	.002	.032
.377	6.520	.634	.026	.450	.036	.025	.051	.068	.059	.004	.047
.380	6.650	.553	.033	.490	.042	.077	.066	.016	.069	.008	.094
.400	6.150	.582	.032	.481	.045	.134	.059	.010	.072	.008	.041
.400	6.010	.540	.025	.472	.033	.141	.047	.033	.051	.013	.062
.400	6.180	.575	.029	.436	.037	.089	.058	.092	.061	.003	.083
.420	6.430	.615	.058	.487	.072	.127	.113	.016	.119	.060	.162
.446	5.640	.550	.030	.553	.042	.104	.055	.031	.069	.004	.031
.453	5.780	.567	.033	.582	.046	.182	.062	.092	.076	.033	.040
.455	5.760	.575	.023	.641	.029	.248	.044	.178	.046	.050	.060
.460	6.200	.636	.036	.626	.044	.335	.070	.220	.073	.054	.100
.477	5.820	.671	.012	.642	.015	.253	.025	.107	.026	.045	.035
.480	6.000	.610	.018	.611	.022	.245	.035	.140	.037	.036	.050
.500	5.720	.621	.016	.729	.023	.207	.030	.157	.036	.066	.021
.500	5.660	.560	.015	.724	.020	.157	.027	.183	.030	.099	.031
.500	5.940	.529	.005	.640	.007	.116	.011	.143	.012	.106	.016
.520	5.710	.675	.018	.717	.025	.270	.033	.047	.040	.036	.020
.520	5.780	.608	.014	.622	.018	.176	.028	.003	.029	.073	.040
.543	5.430	.702	.021	.730	.030	.320	.040	.073	.051	.004	.018
.545	5.410	.722	.022	.738	.033	.312	.040	.043	.056	.000	.000
.550	5.290	.658	.021	.680	.031	.282	.038	.066	.053	.000	.000
.577	5.330	.781	.021	.831	.029	.353	.040	.057	.048	.008	.030
.580	5.270	.763	.021	.804	.026	.361	.042	.085	.044	.017	.060
.600	5.080	.806	.007	.879	.011	.423	.014	.122	.016	.067	.013
.600	4.860	.789	.009	.855	.013	.433	.017	.145	.018	.100	.020
.600	5.100	.811	.004	.773	.005	.430	.008	.095	.008	.092	.011
.622	4.930	.815	.019	.913	.024	.416	.038	.126	.039	.010	.054
.625	5.250	.840	.021	.973	.026	.412	.041	.150	.043	.039	.059
.645	4.660	.812	.025	.954	.034	.383	.047	.119	.050	.072	.056

TABLE III (Contd.)

E (MEV)	SIG, R	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
.655	4.710	.821	.024	.981	.033	.390	.044	.143	.047	-.063	.051
.660	4.610	.872	.014	1.001	.018	.414	.028	.167	.029	-.103	.040
.680	4.690	.980	.023	1.027	.029	.625	.045	.209	.047	.095	.065
.700	4.530	1.015	.045	1.136	.056	.653	.087	.236	.092	.130	.125
.720	4.590	.930	.030	1.079	.037	.537	.058	.210	.061	-.025	.083
.746	4.300	.966	.021	1.116	.028	.662	.040	.241	.043	.050	.052
.753	4.390	.981	.020	1.175	.027	.689	.038	.291	.041	.056	.049
.755	4.300	.990	.023	1.193	.032	.690	.044	.311	.048	.060	.055
.760	4.320	.963	.016	1.174	.020	.659	.032	.294	.033	-.034	.046
.775	4.480	.986	.022	1.143	.033	.676	.040	.175	.054	.000	.000
.800	4.180	.967	.025	1.092	.031	.682	.049	.183	.052	.001	.071
.800	3.920	.945	.021	1.085	.026	.672	.041	.122	.043	-.033	.059
.825	4.270	.989	.007	1.210	.008	.825	.013	.296	.014	-.042	.019
.845	4.090	1.043	.015	1.217	.021	.871	.027	.278	.034	.042	.013
.855	4.050	1.022	.016	1.206	.023	.827	.030	.287	.037	-.013	.017
.860	3.800	1.000	.012	1.128	.015	.754	.024	.251	.025	-.026	.035
.877	4.040	1.020	.027	1.181	.033	.863	.053	.254	.055	.079	.076
.880	3.820	1.065	.031	1.179	.038	.870	.060	.272	.063	.173	.086
.900	3.910	.969	.022	1.158	.029	.789	.042	.231	.049	-.042	.038
.922	4.120	1.006	.023	1.258	.033	.941	.042	.251	.054	.000	.016
.925	3.930	1.075	.012	1.327	.015	1.018	.023	.324	.024	.000	.033
.945	4.170	.981	.020	1.245	.025	.922	.040	.272	.042	-.014	.057
.950	4.260	1.038	.029	1.311	.037	1.043	.058	.361	.061	.053	.083
.977	4.200	.984	.030	1.303	.038	.973	.060	.325	.063	.008	.086
.980	4.120	.962	.010	1.226	.013	1.014	.021	.296	.022	.106	.030
1.000	4.090	1.013	.023	1.270	.029	1.037	.046	.233	.048	.016	.066
1.000	3.990	1.034	.010	1.262	.012	1.041	.019	.227	.020	.019	.028
1.000	4.000	1.105	.003	1.291	.003	1.070	.006	.342	.006	.019	.008
1.020	3.980	1.034	.027	1.229	.034	.958	.053	.181	.056	-.025	.077
1.020	4.070	1.027	.026	1.265	.032	1.012	.050	.188	.053	.012	.072
1.040	3.830	1.060	.018	1.223	.023	1.014	.036	.294	.039	-.047	.053
1.040	3.980	1.040	.014	1.242	.018	1.010	.028	.211	.030	-.080	.041
1.060	3.800	1.088	.026	1.249	.034	.976	.048	.202	.056	-.063	.044
1.060	3.600	1.076	.032	1.228	.039	.975	.062	.307	.065	-.126	.089
1.080	4.000	1.072	.038	1.273	.053	1.093	.070	.291	.087	-.056	.042

TABLE III (Contd.)

E(MEV)	SIG.R	W1	DW1	W2	DW2	W3	DW3	W4	DW4	W5	DW5
1.080	3.830	1.041	.030	1.240	.038	1.040	.059	.302	.062	.112	.085
1.100	3.940	1.197	.022	1.332	.027	1.151	.043	.343	.046	.044	.062
1.100	3.780	1.171	.031	1.287	.038	1.088	.061	.311	.064	.045	.087
1.122	3.910	1.171	.030	1.352	.038	1.142	.059	.426	.062	.040	.085
1.125	4.180	1.268	.032	1.483	.040	1.195	.063	.449	.066	.075	.090
1.145	3.970	1.232	.016	1.396	.020	1.228	.031	.428	.033	.019	.045
1.155	4.020	1.215	.017	1.381	.021	1.223	.034	.451	.036	.030	.049
1.160	3.960	1.133	.023	1.258	.028	1.082	.044	.396	.047	.093	.064
1.175	4.400	1.269	.024	1.422	.030	1.226	.047	.338	.049	.098	.067
1.200	4.140	1.175	.045	1.380	.063	1.346	.082	.382	.103	.021	.040
1.200	4.060	1.105	.029	1.363	.036	1.272	.057	.402	.060	.043	.081
1.223	3.940	1.273	.031	1.462	.045	1.401	.055	.378	.074	.051	.009
1.225	3.980	1.276	.042	1.462	.051	1.409	.073	.409	.100	.000	.000
1.225	4.110	1.279	.044	1.464	.054	1.474	.076	.477	.105	.000	.000
1.246	3.810	1.256	.034	1.428	.043	1.352	.067	.333	.070	.002	.096
1.253	3.790	1.224	.044	1.431	.055	1.294	.086	.283	.090	.121	.123
1.255	3.860	1.210	.060	1.427	.075	1.285	.117	.308	.123	.175	.168
1.276	3.830	1.253	.040	1.442	.054	1.403	.073	.372	.090	.013	.051
1.277	3.860	1.239	.053	1.423	.073	1.430	.097	.379	.121	.020	.057
1.280	3.550	1.262	.041	1.464	.051	1.353	.080	.323	.085	.041	.115
1.300	4.000	1.292	.032	1.484	.041	1.322	.064	.325	.067	.066	.092
1.322	3.970	1.225	.044	1.421	.055	1.345	.086	.316	.091	.045	.124
1.325	3.820	1.237	.045	1.419	.056	1.542	.087	.470	.092	.198	.125
1.353	3.970	1.251	.035	1.500	.046	1.439	.067	.328	.075	.071	.102
1.355	4.200	1.287	.038	1.569	.047	1.363	.074	.310	.078	.040	.106
1.360	4.180	1.183	.061	1.510	.076	1.225	.119	.190	.125	.114	.170
1.377	3.890	1.333	.035	1.529	.043	1.428	.069	.290	.072	.085	.099
1.380	3.970	1.271	.046	1.496	.057	1.399	.090	.231	.095	.103	.129
1.400	4.000	1.328	.040	1.530	.050	1.495	.079	.303	.083	.188	.114
1.400	3.800	1.404	.038	1.565	.048	1.550	.075	.365	.079	.163	.108
1.422	3.750	1.297	.068	1.457	.085	1.406	.134	.262	.140	.018	.192
1.425	3.590	1.396	.031	1.492	.039	1.493	.061	.366	.064	.052	.088
1.450	3.810	1.334	.052	1.524	.072	1.639	.097	.378	.116	.176	.158
1.450	3.840	1.427	.044	1.568	.055	1.521	.086	.394	.091	.008	.124
1.500	3.970	1.458	.032	1.613	.039	1.512	.062	.350	.065	.041	.089

TABLE IV. Inelastic Excitation Cross Sections of Tantalum

a. $Q = -0.144 \pm 0.010$ MeV (doublet)

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.450	.980	.230	.475	.985	.148	.500	.855	.080
.520	.994	.105	.540	.998	.105	.577	.954	.101
.600	.912	.096	.618	.903	.067	.645	.876	.093
.660	.825	.072	.680	.794	.076	.700	.876	.074
.720	.848	.085	.746	.870	.075	.767	.900	.095
.800	.935	.094	.832	.904	.096	.853	.897	.077
.877	.917	.097	.899	.916	.075	.920	.871	.130
.932	.877	.093	.952	.919	.055	.977	.866	.091
1.000	.850	.058	1.020	.760	.070	1.050	.915	.087
1.060	.880	.102	1.080	.697	.104	1.100	.841	.074
1.120	.834	.125	1.150	.925	.077	1.170	.901	.135
1.200	.766	.072	1.220	.790	.118	1.250	.798	.058
1.270	.809	.121	1.300	.738	.081	1.350	.776	.116
1.400	.620	.150	1.420	.680	.102	1.500	.590	.100
1.550	.563	.090						

b. $Q = -0.313 \pm 0.015$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.600	.450	.067	.625	.397	.059	.650	.340	.054
.750	.440	.047	.775	.498	.074	.800	.444	.066
.821	.461	.040	.853	.464	.036	.877	.446	.047
.899	.439	.038	.925	.423	.063	.949	.461	.034
.977	.468	.049	1.000	.420	.031	1.020	.431	.045
1.040	.467	.050	1.055	.408	.031	1.080	.431	.046
1.100	.421	.047	1.120	.415	.044	1.140	.421	.063
1.150	.436	.065	1.152	.396	.024	1.200	.430	.049
1.220	.492	.073	1.250	.431	.045	1.270	.469	.070
1.300	.389	.045	1.320	.409	.061	1.350	.401	.036
1.370	.373	.056	1.400	.398	.045	1.420	.409	.061
1.450	.398	.043	1.500	.409	.049	1.550	.423	.065

c. $Q = -0.506 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.800	.322	.066	.853	.454	.060	.880	.559	.100
.900	.537	.105	.920	.490	.097	.925	.497	.098
.949	.406	.064	.974	.512	.099	1.000	.526	.072
1.055	.562	.080	1.100	.462	.090	1.120	.503	.096
1.150	.353	.051	1.170	.491	.095	1.200	.496	.095
1.220	.515	.098	1.270	.440	.091	1.300	.479	.096
1.320	.517	.101	1.350	.402	.061	1.370	.315	.076
1.400	.387	.086	1.420	.334	.079	1.470	.325	.079
1.362	.340	.042	1.550	.298	.080			

TABLE IV (Contd.)

d. $Q = -0.620 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.949	.504	.186	1.000	.440	.074	1.060	.440	.066
1.100	.505	.075	1.120	.448	.047	1.140	.441	.066
1.153	.454	.033	1.175	.441	.047	1.200	.406	.045
1.220	.478	.071	1.250	.495	.040	1.270	.500	.075
1.300	.475	.071	1.320	.510	.076	1.350	.468	.051
1.370	.476	.071	1.400	.389	.060	1.420	.351	.052
1.450	.469	.054	1.470	.440	.066	1.500	.375	.056
1.550	.432	.067						

e. $Q = -0.720 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.150	.431	.026	1.200	.457	.084	1.220	.488	.073
1.250	.417	.028	1.270	.531	.079	1.300	.460	.084
1.320	.493	.073	1.350	.433	.030	1.360	.351	.039
1.400	.521	.083	1.420	.480	.072	1.450	.510	.041
1.470	.467	.070	1.500	.421	.081	1.550	.560	.082

f. $Q = -0.930 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.400	.150	.050	1.420	.127	.019	1.500	.150	.050
1.550	.144	.024						

TABLE V. Inelastic Excitation Cross Sections of Rhenium

a. $Q = -0.132 \pm 0.010$ MeV (Complex of States)

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.375	.916	.087	.400	.750	.112	.425	.770	.200
.475	.828	.070	.500	.819	.123	.520	.853	.090
.540	.801	.119	.550	.755	.150	.576	.845	.076
.600	.803	.085	.620	.722	.108	.632	.763	.081
.653	.801	.075	.677	.709	.067	.700	.744	.111
.720	.800	.120	.728	.701	.055	.752	.770	.065
.775	.769	.063	.800	.741	.078	.832	.751	.071
.853	.766	.066	.876	.742	.066	.899	.679	.058
.920	.633	.095	.928	.623	.080	.952	.616	.048
.976	.596	.045	1.000	.567	.042	1.020	.534	.056
1.032	.484	.047	1.060	.459	.068	1.100	.585	.087
1.125	.490	.100	1.152	.553	.051	1.175	.523	.056
1.200	.564	.108	1.220	.494	.074	1.250	.559	.049
1.270	.504	.075	1.300	.423	.063	1.350	.506	.053
1.370	.450	.067	1.400	.433	.064	1.450	.556	.090
1.550	.361	.065						

b. $Q = -0.219 \pm 0.015$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.500	.243	.036	.575	.192	.040	.600	.241	.036
.625	.213	.031	.650	.185	.100	.725	.213	.032
.750	.280	.030	.760	.207	.031	.775	.192	.018
.824	.188	.022	.849	.243	.026	.875	.191	.017
.900	.192	.028	.924	.169	.019	.949	.225	.024
.974	.171	.019	1.000	.183	.019	1.025	.146	.030
1.050	.233	.034	1.075	.180	.030	1.150	.168	.023
1.250	.123	.021						

c. $Q = -0.313 \pm 0.015$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.600	.534	.080	.625	.472	.070	.650	.479	.077
.675	.471	.064	.750	.491	.040	.775	.413	.035
.800	.429	.064	.827	.414	.028	.849	.439	.031
.875	.397	.046	.900	.413	.061	.920	.450	.067
.924	.350	.038	.949	.399	.042	.976	.377	.032
1.000	.433	.038	1.020	.465	.050	1.040	.379	.056
1.053	.380	.034	1.077	.367	.037	1.100	.386	.041
1.153	.424	.036	1.180	.349	.052	1.200	.353	.037
1.250	.368	.040	1.270	.409	.061	1.350	.291	.037
1.370	.361	.054	1.400	.381	.057	1.420	.332	.049
1.450	.399	.053	1.500	.303	.045	1.550	.254	.038

TABLE V (Contd.)

d. $Q = -0.387 \pm 0.018$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.775	.271	.040	.800	.170	.025	.824	.210	.031
.849	.251	.031	.875	.254	.038	.900	.213	.031
.925	.195	.029	.949	.232	.024	.974	.219	.032
1.000	.203	.030	1.050	.271	.040	1.100	.197	.029
1.135	.183	.019	1.250	.135	.020	1.350	.131	.025
1.550	.120	.024						

e. $Q = -0.518 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.880	.245	.062	.900	.277	.077	.925	.224	.069
.949	.247	.051	.974	.250	.069	1.000	.294	.054
1.100	.236	.065	1.120	.290	.070	1.150	.321	.057
1.170	.202	.064	1.200	.247	.067	1.220	.252	.065
1.250	.240	.049	1.270	.262	.068	1.300	.271	.069
1.320	.224	.064	1.350	.194	.039	1.370	.095	.054
1.400	.140	.059	1.550	.150	.049			

f. $Q = -0.637 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.100	.462	.069	1.120	.438	.065	1.150	.596	.070
1.170	.543	.081	1.200	.364	.054	1.220	.484	.072
1.250	.448	.039	1.270	.432	.064	1.300	.434	.065
1.320	.469	.070	1.350	.415	.044	1.370	.419	.062
1.400	.431	.064	1.500	.339	.050	1.550	.419	.062

g. $Q = -0.767 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.050	.569	.105	1.320	.425	.063	1.400	.612	.091
1.450	.469	.067	1.500	.647	.096	1.550	.471	.053

h. $Q = -0.865 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.350	.349	.064	1.450	.304	.124	1.550	.378	.066

TABLE V (Contd.)

i. $Q = -0.963 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.500	.308	.046	1.550	.322	.136

j. $Q = -1.060 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.500	.228	.034	1.550	.320	.056

k. $Q = -1.135 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.500	.263	.039	1.550	.376	.078

TABLE VI. Inelastic Excitation Cross Sections of Platinum

a. $Q = -0.130 \pm 0.20$ MeV, Complex of States, 2 Major Components Separated by ~ 30 keV.

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.450	.289	.110	.500	.200	.050	.520	.239	.035
.540	.250	.026	.550	.238	.031	.577	.239	.025
.600	.213	.023	.620	.220	.033	.632	.212	.022
.655	.206	.025	.680	.242	.036	.700	.217	.028
.750	.164	.020	.775	.204	.030	.800	.241	.034
.824	.200	.030	.849	.195	.023	.900	.225	.033
.924	.186	.019	.974	.198	.029	1.000	.181	.019
1.100	.179	.026	1.150	.145	.017	1.350	.153	.021
1.550	.228	.039						

b. $Q = -0.214 \pm 0.020$ MeV, Complex of States

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.600	.300	.070	.625	.324	.048	.650	.362	.057
.700	.288	.070	.752	.362	.030	.775	.267	.040
.799	.300	.030	.832	.279	.029	.852	.273	.024
.877	.269	.028	.900	.246	.040	.925	.239	.035
.949	.268	.029	.977	.217	.023	1.000	.240	.036
1.020	.241	.036	1.040	.257	.027	1.055	.247	.023
1.080	.269	.040	1.100	.243	.028	1.120	.229	.024
1.150	.228	.029	1.170	.233	.035	1.200	.240	.036
1.220	.263	.039	1.250	.213	.025	1.270	.235	.035
1.300	.208	.038	1.370	.203	.030	1.400	.224	.038
1.420	.231	.034	1.450	.200	.033	1.500	.162	.060

c. $Q = -0.348 \pm 0.015$ MeV, Apparent Single State

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.800	.603	.090	.949	.608	.064	.974	.578	.086
1.000	.600	.090	1.100	.510	.076	1.150	.542	.075

d. $Q = -0.420 \pm 0.015$ MeV Apparent Single State

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.800	.163	.024	.849	.308	.058	.949	.251	.027
.974	.228	.034	1.000	.252	.037	1.100	.250	.037
1.150	.229	.040						

TABLE VI (Contd.)

e. $Q = -0.360$ Composite of c and d Above

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
.625	.778	.117	.680	.683	.102	.700	.742	.111
.740	.742	.111	.750	.616	.065	.800	.757	.057
.832	.643	.068	.853	.634	.051	.877	.660	.070
.900	.663	.070	.920	.735	.110	.925	.601	.090
.952	.743	.056	.977	.744	.055	1.000	.710	.050
1.020	.696	.073	1.040	.734	.110	1.052	.523	.050
1.080	.636	.095	1.100	.708	.077	1.120	.645	.068
1.150	.662	.063	1.175	.719	.076	1.200	.678	.072
1.220	.709	.106	1.250	.608	.065	1.270	.665	.099
1.300	.694	.104	1.320	.650	.097	1.350	.612	.064
1.370	.613	.091	1.400	.620	.093	1.420	.668	.100
1.450	.666	.090	1.550	.679	.106			

f. $Q = -0.620 \pm 0.020$ MeV, Apparent Single State

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.000	.317	.047	1.060	.275	.041	1.100	.318	.047
1.120	.276	.041	1.150	.341	.046	1.170	.298	.044
1.200	.315	.047	1.220	.262	.039	1.250	.285	.032
1.290	.301	.040	1.350	.400	.065	1.400	.372	.055
1.450	.329	.055	1.550	.306	.047			

g. $Q = -0.719 \pm 0.015$ MeV, Apparent Single State

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.120	.228	.034	1.150	.332	.048	1.170	.259	.038
1.220	.236	.035	1.250	.163	.031	1.270	.289	.043
1.350	.326	.063	1.400	.326	.039	1.450	.272	.045
1.550	.314	.054						

h. $Q = -0.655$ Composite of f and g Above

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1.050	.500	.083	1.120	.504	.034	1.150	.560	.041
1.170	.558	.044	1.220	.500	.035	1.250	.380	.036
1.270	.614	.050	1.300	.432	.064	1.320	.557	.083
1.350	.654	.051	1.370	.484	.072	1.400	.560	.029
1.420	.517	.077	1.450	.628	.062	1.500	.515	.077
1.550	.620	.054						

TABLE VI (Contd.)

i. $Q = -0.838 \pm 0.025$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1,250	.270	.011	1,350	.212	.013	1,420	.349	.052
1,500	.256	.038	1,550	.223	.049			

j. $Q = -0.935 \pm 0.020$ MeV

EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.	EN(MEV)	SIG. B	D-SIG.
1,250	.329	.059	1,450	.222	.023	1,500	.263	.039
1,550	.305	.035						

TABLE VII. Total Neutron Cross Sections of Tantalum

EN(KEV)	SIG.B	EN(KEV)	SIG.B	EN(KEV)	SIG.B
100.29	9.190	101.29	8.850	102.29	8.940
103.39	9.050	104.39	9.150	105.39	9.030
106.39	8.780	107.39	8.940	108.39	8.880
109.39	9.370	110.39	8.590	111.39	8.730
112.39	8.530	113.49	8.840	114.49	8.720
115.49	8.810	116.49	8.670	117.49	8.700
118.49	8.470	119.49	8.640	120.49	8.710
121.49	8.560	122.49	8.320	123.49	8.470
124.49	8.470	125.49	8.520	126.49	8.420
127.49	8.370	128.49	8.190	129.49	8.499
129.49	8.499	130.49	8.350	131.50	8.300
132.50	8.360	133.50	8.670	134.59	7.730
135.59	8.160	136.59	8.400	137.59	8.270
138.59	8.190	139.59	8.320	140.59	8.240
141.59	8.420	142.59	8.100	143.59	8.280
144.59	8.300	145.59	7.740	146.59	7.630
147.59	8.140	148.59	8.050	149.59	8.140
150.59	8.020	151.59	8.210	152.59	8.100
153.59	8.150	154.59	8.050	155.59	8.220
156.59	8.220	157.59	8.090	158.59	8.040
159.59	7.980	161.59	8.070	162.59	7.840
163.59	8.080	164.59	8.270	165.59	8.060
166.59	7.900	167.59	8.100	168.59	7.800
169.59	7.830	170.59	7.690	171.59	8.200
172.59	8.060	173.69	8.230	174.69	7.870
175.69	7.670	176.69	8.060	177.69	8.120
178.69	7.970	179.69	8.040	180.69	8.110
181.69	7.700	182.69	8.030	183.69	8.080
184.69	7.910	185.69	7.749	186.69	7.550
187.69	8.030	188.69	8.010	189.69	7.800
190.69	8.100	191.69	7.890	192.69	8.170
193.69	7.749	194.69	7.580	195.69	8.100
196.69	7.840	197.69	7.860	198.69	7.670
199.69	7.810	200.69	7.720	201.69	7.650
202.69	7.760	203.69	7.749	204.69	7.480
205.69	7.730	206.69	8.450	207.69	8.010
208.69	7.810	209.69	7.740	210.69	8.050
211.69	7.840	212.69	7.749	213.69	7.580
214.69	7.570	215.69	7.880	216.69	7.460
217.69	7.800	218.69	7.600	219.69	7.700
220.69	7.810	221.69	7.560	222.69	7.510
223.69	7.570	224.69	7.430	225.69	7.960
226.69	7.540	227.69	7.749	228.69	7.720
229.69	7.550	230.69	7.570	231.69	7.690
232.69	7.710	233.69	7.850	234.69	7.550

TABLE VII. (Contd.)

EN(KEV)	SIG.B	EN(KEV)	SIG.B	EN(KEV)	SIG.B
235.69	7.530	236.79	7.730	237.79	7.760
238.79	7.510	239.79	7.249	240.79	7.260
241.79	7.350	242.79	7.670	243.79	7.720
244.79	7.440	245.79	7.690	246.79	7.310
247.79	7.660	248.79	7.430	249.79	7.240
250.79	7.630	251.79	7.320	252.79	7.360
253.79	7.660	254.79	7.880	255.79	7.480
256.79	7.400	257.79	7.390	258.79	7.280
259.79	7.790	260.79	7.340	261.79	7.660
262.79	7.260	263.79	7.590	264.79	7.480
265.80	7.440	266.79	7.660	267.79	7.240
268.79	7.490	269.79	7.530	270.79	7.400
271.79	7.310	272.79	7.390	273.79	7.060
274.79	7.470	275.79	7.310	276.79	7.350
277.79	7.140	278.79	7.510	279.79	7.249
280.79	7.110	281.79	7.390	282.79	7.320
283.79	7.740	284.89	7.120	285.89	7.320
286.89	7.330	287.89	7.740	288.89	7.200
289.89	7.130	290.89	7.300	291.90	7.030
292.89	7.270	293.89	7.190	294.89	7.300
295.89	7.470	296.89	7.260	297.89	7.050
298.89	7.520	299.89	7.290	300.89	7.300
301.89	7.380	302.89	7.440	303.89	7.020
304.89	7.400	305.89	7.380	306.89	7.160
307.89	7.270	308.89	7.400	309.89	7.150
310.89	7.270	311.89	7.270	312.89	7.150
313.89	7.350	314.89	7.420	315.89	7.120
316.89	7.290	317.89	7.120	318.89	7.280
319.89	7.330	321.00	7.420	321.99	7.050
323.00	7.260	323.99	7.100	324.99	7.280
325.99	6.999	326.99	6.810	327.99	7.150
329.00	7.260	329.99	7.090	330.99	6.999
331.99	7.440	333.00	7.140	333.99	6.990
335.00	7.120	335.99	7.460	336.99	7.070
337.99	6.990	339.00	7.210	339.99	7.150
341.00	7.310	341.99	7.540	342.99	7.240
343.99	7.050	344.99	7.070	345.99	7.090
346.99	6.749	347.99	7.260	348.99	6.780
349.99	7.120	351.00	6.910	351.99	7.100
352.99	7.230	353.99	6.980	355.00	7.390
355.99	6.890	357.00	6.830	357.99	7.200
358.99	7.150	359.99	7.150	361.00	6.960
361.99	7.040	363.00	7.270	363.99	6.950
364.99	7.010	365.99	7.180	366.99	7.110
367.99	6.660	368.99	6.970	369.99	7.220

TABLE VII (Contd.)

EN(KEV)	SIG.B	EN(KEV)	SIG.B	EN(KEV)	SIG.B
370.99	7.249	371.99	7.060	372.99	7.060
373.99	7.200	375.00	7.200	375.99	7.260
377.00	6.870	377.99	7.070	379.00	6.790
379.99	7.130	380.99	6.740	381.99	7.120
383.00	6.970	383.99	7.020	384.99	7.160
385.99	6.980	386.99	6.940	387.99	6.910
388.99	6.970	389.99	7.100	390.99	7.340
391.99	6.970	393.99	6.840	394.99	7.240
395.99	7.110	397.00	7.150	397.99	7.010
399.00	6.920	399.99	6.950	401.00	7.290
401.99	7.130	403.00	7.020	403.99	6.960
404.99	7.150	405.99	7.310	406.99	6.950
407.99	6.970	408.99	6.860	409.99	7.560
410.99	6.870	411.99	6.690	412.99	6.840
413.99	6.780	414.99	6.860	415.99	6.749
416.99	6.900	417.99	6.830	419.00	7.150
419.99	7.190	421.00	7.180	421.99	6.749
422.99	6.890	423.99	7.100	424.99	6.940
425.99	6.930	426.99	6.890	427.99	6.930
428.99	6.850	429.99	7.110	430.99	7.350
432.99	7.090	433.99	6.870	434.99	7.120
435.99	7.070	436.99	7.090	437.99	6.810
438.99	7.180	439.99	7.060	443.99	7.320
444.99	7.160	445.99	7.170	446.99	6.660
447.99	6.780	448.99	6.999	449.99	7.060
450.99	6.960	451.99	6.990	452.99	6.980
453.99	7.040	454.99	6.900	455.99	7.100
456.99	6.630	457.99	6.980	458.99	6.820
459.99	6.850	460.99	6.980	461.99	6.990
462.99	7.070	463.99	6.960	464.99	6.730
465.99	6.870	466.99	6.760	467.99	7.060
468.99	6.890	469.99	6.890	470.99	6.910
471.99	6.960	472.99	6.680	473.99	6.960
475.09	7.030	476.09	7.030	477.09	6.670
478.09	6.970	479.09	7.070	480.09	7.130
481.09	6.960	482.09	7.030	483.09	6.880
484.09	7.070	485.09	6.980	487.09	6.780
488.09	6.770	489.09	7.090	490.09	6.940
491.09	6.920	492.09	6.780	493.09	6.820
494.09	6.830	495.09	7.130	496.09	6.730
497.09	6.850	498.09	7.030	499.09	7.270
500.09	6.770	501.09	7.170	502.09	7.050
503.09	7.530	504.09	7.080	505.09	6.810
506.09	6.910	507.09	7.040	508.09	7.240
509.09	6.870	510.09	6.940	511.09	6.900
512.09	6.840	513.09	6.930	514.09	7.030

TABLE VII (Contd.)

EN(KEV)	SIG.B	EN(KEV)	SIG.B	EN(KEV)	SIG.B
515.09	7.060	516.09	7.010	517.09	7.220
518.09	7.040	519.09	6.960	520.09	6.990
521.09	6.640	522.09	6.999	523.09	7.110
524.09	6.749	525.09	6.940	527.09	6.800
528.09	6.840	529.09	6.740	530.09	6.880
531.09	6.850	532.10	6.790	533.09	6.610
534.09	6.710	535.09	6.860	536.09	6.740
537.09	6.910	538.09	6.850	539.10	6.870
540.09	6.810	541.09	6.760	542.09	6.700
543.10	6.810	544.09	6.840	545.09	6.820
546.09	6.840	547.09	6.550	548.09	6.870
549.09	6.850	550.10	6.960	551.09	6.890
552.09	6.780	553.09	6.930	554.09	6.790
555.09	6.910	556.09	6.880	557.09	6.780
558.09	6.760	559.09	6.990	560.09	7.180
561.09	6.710	562.09	6.870	563.09	6.660
564.09	7.270	565.09	6.930	566.09	6.900
567.09	6.950	568.09	6.530	569.09	6.749
570.09	6.890	571.09	6.990	572.09	6.830
573.09	6.820	574.09	6.580	575.09	6.720
576.09	6.890	577.09	6.890	578.09	6.990
579.09	7.130	580.09	7.030	581.09	6.760
582.09	6.540	583.10	6.910	584.09	7.100
585.09	7.110	586.09	6.650	587.09	6.560
588.09	6.740	589.09	6.810	590.09	6.760
591.09	6.870	592.09	6.810	593.09	6.800
594.09	6.770	595.09	6.970	596.09	6.800
597.09	6.590	598.09	6.900	599.09	6.880
600.09	6.770	601.09	6.540	602.09	7.110
603.09	6.520	604.09	6.999	605.09	6.749
606.09	7.210	607.09	6.600	608.09	6.720
609.09	6.650	610.09	7.030	611.09	6.760
612.09	6.690	613.09	7.010	614.09	6.040
615.09	6.860	616.09	6.870	617.09	6.730
618.09	6.810	619.09	6.880	620.09	6.720
621.09	6.900	622.09	7.120	623.09	6.870
624.09	6.900	625.09	6.670	626.09	6.570
627.09	6.790	628.09	6.850	629.09	7.080
630.09	6.820	631.09	7.040	632.09	6.810
633.09	6.660	634.09	6.970	635.09	6.840
636.09	6.499	637.09	6.650	638.09	6.640
639.09	6.960	640.09	7.090	641.09	6.650
642.09	6.880	643.09	6.720	644.09	6.510
645.09	6.820	646.09	6.960	647.09	6.480

TABLE VIII. Total Neutron Cross Sections of Rhenium

EN(KEV)	SIG.B	EN(KEV)	SIG.B	EN(KEV)	SIG.B
540.00	6.260	550.00	6.060	560.00	5.950
570.00	6.030	580.00	5.880	590.00	5.770
600.00	5.990	610.00	6.540	615.00	6.550
620.00	5.850	625.00	6.170	630.00	6.210
640.00	6.340	650.00	5.860	660.00	6.310
700.00	6.360	710.00	5.850	720.00	6.260
730.00	6.420	740.00	5.960	750.00	6.170
760.00	6.450	770.00	6.300	780.00	6.330
790.00	6.129	822.50	6.790	832.50	6.670
842.50	6.560	852.50	6.870	862.50	6.580
872.50	6.540	882.50	6.550	892.50	6.650
902.50	6.680	912.50	6.640	922.50	6.750
932.50	6.340	942.50	6.880	952.50	6.760
962.50	6.670	972.50	6.770	982.50	6.740
992.50	6.890	1010.00	6.680	1020.00	6.814
1025.00	6.490	1030.00	6.710	1040.00	7.010
1050.00	6.494	1060.00	6.490	1070.00	6.560
1080.00	6.534	1090.00	6.670	1100.00	6.750
1110.00	6.414	1120.00	6.740	1130.00	6.570
1140.00	6.544	1150.00	6.830	1160.00	7.020
1170.00	6.714	1180.00	6.500	1190.00	6.590
1200.00	6.264	1210.00	6.660	1220.00	6.770
1230.00	6.800	1235.00	6.550	1240.00	7.190
1245.00	6.360	1250.00	6.750	1255.00	6.460
1260.00	6.530	1265.00	6.680	1270.00	6.680
1275.00	6.600	1280.00	6.510	1285.00	6.840
1290.00	6.800	1295.00	6.600	1300.00	6.250
1305.00	7.160	1310.00	6.990	1315.00	6.400
1320.00	6.670	1325.00	6.660	1330.00	6.190
1335.00	6.420	1340.00	6.460	1345.00	6.610
1350.00	6.760	1355.00	6.530	1360.00	6.860
1365.00	6.750	1370.00	7.420	1375.00	6.680
1380.00	6.660	1385.00	6.770	1390.00	6.890
1395.00	6.800	1400.00	7.000	1410.00	6.584
1420.00	6.750	1430.00	6.460	1440.00	6.504
1450.00	6.450	1460.00	6.780	1470.00	6.934
1480.00	6.758	1490.00	6.710	1500.00	6.434

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