The $B(M1)$ values for the $2' \rightarrow 2$ transition are exceedingly small compared to the single-particle estimate. These small values are in qualitative agreement with the collective models, i.e., $M1$ radiation is forbidden in the decay of vibrational excitations.

In Table V the ratios of $B(E2)$ are compared with the predictions of the various collective models. The strong coupling model for axial symmetric nuclei predicts that $B(E2, 2' \rightarrow 2)/B(E2, 2' \rightarrow 0)$ is 1.43. The observed values for W^{184} and W^{186} are appreciably larger. The models for vibrations of spherical nuclei and "shape unstable" nuclei predict (in the simplest approximation) that $B(E2, \ 2' \rightarrow 2)/B(E2, \ 2 \rightarrow 0)$ should be 2. The observed values for Pt^{194} and Os^{192} are somewhat less than 2.

The predictions of the asymmetric rotor model of Davydov and Filippov[4] are particularly interesting since this model offers a possible quantitative interpretation of collective motion in a transition region such as that represented by the osmium nuclei. The positions of the first and second 2+ states and the first 4+ state are shown in Fig. 4 for the even-A nuclei of wolfram, osmium, and platinum. According to the Davydov-Filippov model the parameter γ, which measures the departure from axial symmetry, can be obtained from the ratio of the energies of the first and second 2+ states. When one has the value for γ and the energy of the first 2+ state, one can then predict the expected positions of the first 4+ state. The expected locations of the 4+ state are indicated by arrows in Fig. 4. There is rather good agreement between the predicted locations and the observed locations of the first 4+ state.

The Davydov-Filippov model also makes quantitative predictions for the ratios of $B(E2)$ for these nuclei. In Table V we have compared our results with the predictions of this model. The model predicts quite well the observed trends in the ratios of the $B(E2)$'s and, in fact, there is considerable quantitative agreement.

PHYSICAL REVIEW VOLUME 122, NUMBER 4 MAY 15, 1961

Fast Neutron Activation Cross Section of Au^{197}†

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(Received November 3, 1960)

The neutron activation cross section of gold was measured in the neutron range from 30–1500 kev. The absolute value of the cross section was based on the U^{235} fast fission cross section which was used for absolute neutron flux measurements from 200–1500 kev. For measurements below 200 kev, the $B^{10}(n,\alpha)$ cross section was used for monitoring the neutron flux. The relative cross section from 30–200 kev was then normalized at 200 kev to the absolute measurement. The results agree well with recent measurements, except for some pulsed beam—liquid scintillator measurements and spherical shell transmission measurements which yield much lower cross section values.

INTRODUCTION

A KNOWLEDGE of the absolute value and energy dependence of neutron capture cross sections is important to the design of nuclear reactors. Previously there has been considerable disagreement between measurements made by different groups in both the absolute value and energy dependence of capture cross sections. To a large degree, the disagreement in the absolute value of the capture cross section has been removed in the region of incident neutron energy above approximately 200 kev. However, disagreement in the shape and absolute value of the cross section below 200 kev still exists. This measurement is presented to give additional information on both points for the gold activation cross section.

† Work performed under the auspices of the U. S. Atomic Energy Commission.

EXPERIMENTAL PROCEDURE

The analyzed proton beam from the Argonne 3-Mev Van de Graaff accelerator was used to produce neutrons from the $Li^7(p,n)Be^7$ reaction. The lithium films were evaporated in vacuum onto tantalum target cups. For gold irradiations in the neutron energy range from 20–200 kev, the lithium targets were 10–20 kev thick to the incident protons. For irradiations with neutron energies above 200 kev, the lithium targets were approximately 50 kev thick to the incident protons. The gold was irradiated for approximately one-half hour and then was immediately transferred to a shielded NaI(Tl) scintillation spectrometer where the gamma ray activity was measured. All gold samples were counted within a few minutes after irradiation. The activation cross section was calculated from the known integrated neutron flux, the known gamma-ray efficiency of the scintillation

spectrometer, the known mass of the gold sample, and the known decay constant of the gold beta activity.

The U^{235} fission cross section was chosen as the most suitable cross section for use with an absolute neutron flux monitor.[1] The U^{235} fission cross section was known to approximately $\pm 5\%$ above an incident neutron energy of 200 kev. For incident neutron energies below 200 kev the known shape of the $B^{10}(n,\alpha)Li^{7}$ [2] cross section was used, and the gold activation cross section determined relative to this reaction was normalized to the absolute activation cross section as determined from the U^{235} fission cross section. Both the U^{235} and B^{10} were deposited as thin films. The mass of the U^{235} deposit was determined from absolute alpha counting and mass spectrographic analysis. The estimated total error in the mass determination was $\pm 3\%$. Most of the error was due to uncertainty in the half-life for alpha decay of U^{235}.[3] The fission fragments from the $U^{235}(nf,)$ reaction and the alpha particles from the $B^{10}(n,\alpha)$ reaction were detected by a parallel plate electron collection chamber in 2π geometry. Irradiations were made at 0° with respect to the incident proton beam for neutron energies from 200–1500 kev ,and at 60° with respect to the incident proton beam for neutron energies from 30–200 kev. Irradiations were also made at 135° with respect to the incident proton beam with a long counter used as a neutron monitor. The agreement between the 60° and 135° measurements was approximately $\pm 5\%$. The sensitivity of the long counter as a function of neutron energy was measured relative to the sensitivity of a cadmium-covered BF_3 counter. The geometry for each of the three methods used is shown in Fig. 1. The figures are self-explanatory.

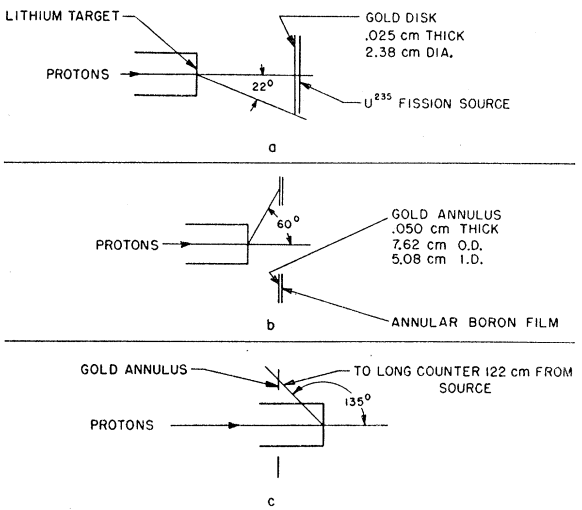

FIG. 1. The experimental arrangement for activation measurements from $E_n=200$ kev to $E_n=1500$ kev is shown in Fig. 1(a). Fig. 1(b) and 1(c) show the experimental arrangements for activation measurements from $E_n=30$ kev to $E_n=200$ kev.

TABLE I. Gold activation cross section.

E_n (kev)	σ activation (barns)	E_n (kev)	σ activation (barns)
30	1.129	500	0.172
50	0.855	600	0.137
60	0.729	700	0.124
77.5	0.655	800	0.110
100	0.556	900	0.102
150	0.403	1000	0.095
200	0.345	1100	0.083
250	0.320	1200	0.091
300	0.284	1300	0.082
400	0.214	1400	0.077
		1500	0.078

The efficiency of the gamma ray counter was measured by standard beta-gamma coincident counting techniques[4] and by comparison of the gamma activity with absolute beta counting in a 4π beta counter. A gold leaf, cut to the same diameter as the gold disks used in the 0° activations, was irradiated in the isotope tray of the Argonne research reactor. The active gold leaf was beta-gamma counted in the same geometry as the gold disks used in the 0° irradiations. Both the gamma detector and the beta detector were sufficiently close to 2π geometry that a beta-gamma correlation would not have affected the measurement appreciably. The efficiency of the gamma counter was $13.2\%\pm 0.4\%$.

The following corrections were made to the data: For neutron energies in excess of approximately 560 kev in the forward direction, the $Li^{7}(p,n)$ reaction yielded two monoergic neutron groups. The relative intensity versus proton energy of the two neutron groups was measured at this laboratory,[5] and a correction was made for the presence of the low-energy group. The correction did not exceed 5%. In the 60° irradiations, the neutron monitor had a solid angle of only 2π steradians for alpha particle collection; thus, a correction for the angular distribution of the alpha particles from the $B^{10}(n,\alpha)$ reaction was necessary. The effect of the angular distribution on the measurement was determined from a measurement of the alpha particle yield with the boron deposit first facing away from the neutron source and then with the monitor rotated 180° so that the boron deposit was facing toward the neutron source. The angular distribution correction did not exceed 8%.

EXPERIMENTAL RESULTS

The results for the gold activation cross section are given in Table I. The low-energy and high-energy measurements are normalized at 200-kev neutron energy. The estimated error in the cross section above 200-kev neutron energy is $\pm 10\%$, and is due primarily

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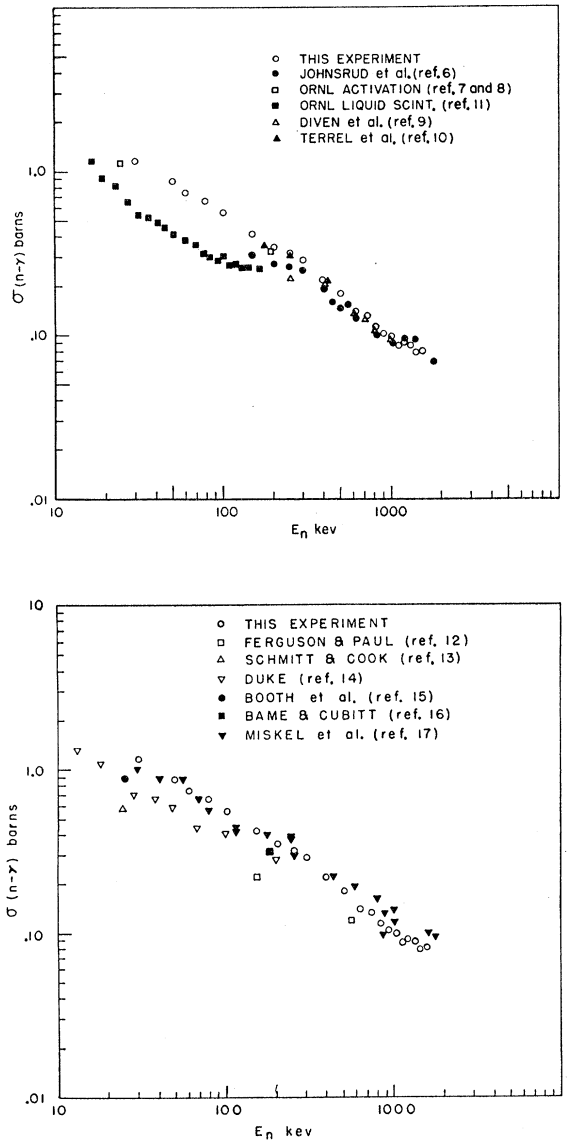

FIG. 2. Comparison of gold neutron capture cross-section measurements.

to the uncertainty in the U^{235} fission cross section and the uncertainty in the efficiency of the gamma-ray detector. The shape of the cross section below 200-kev neutron energy is dependent on the shape of the $B^{10}(n,\alpha)$ cross section used, and on the angular distribution correction described previously. It is difficult to estimate the error in shape for the low energy cross section; however, it should not be large, particularly in the region below 100-kev neutron energy where the $B^{10}(n,\alpha)$ cross section presumably follows the well known $1/v$ law.[2] For comparison, the results of other investigators[6–17] are shown in Fig. 2 along with the present results. The agreement between the results of this experiment and the activation measurements of Johnsrud *et al.*[6] is good for neutron energies above 400 kev. Below 400 kev the cross sections diverge, with our measurements remaining somewhat higher than those of Johnsrud *et al.* Activation measurements reported by Macklin *et al.* at 27 kev,[7] and by Lyon and Macklin at 195 kev[8] are in good agreement with our results. Measurements utilizing the pulsed beam liquid scintillator technique are reported by Diven, and Gibbons *et al.* The agreement with Diven's results[9] is excellent except for the one measurement at 250 kev where Diven's value is much lower than ours. However, some recent results are reported by Terrell *et al.*[10] which indicate much better agreement with our measurements. The agreement between our results and those of Gibbons *et al.*[11] is not good. The cross section reported by Gibbons *et al.* is approximately one-half of ours, and there is a significant difference in the shape of the cross section between 100 and 170 kev. The difference in shape may be explained by some systematic error in neutron monitoring techniques; but the reason for the large difference in absolute value of the cross section is not understood. In this connection it should be noted that the cross section as obtained by Gibbons *et al.* was normalized to the results of Schmitt and Cook[13] who used the spherical shell transmission method.

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