# Neutron-Induced Fission Cross Section of $Pu^{241}$ Below 11 eV*

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The cross section for neutron-induced fission of $Pu^{241}$ for neutron energies below 11 eV has been determined. The determination was made using a gas scintillation counter. The multilevel analysis of these data is in agreement with that predicted from the previous analysis of the total cross section.

## INTRODUCTION

SLOW neutron fission cross-section measurements are of both theoretical and practical interest. In the design of plutonium reactors, this cross section is necessary for the study of long-term reactivity changes and neutron economy. In addition, the analysis of the fission cross section is expected to give added information concerning the fission process. In the analysis of the total cross section of $Pu^{241}$, Simpson and Moore[1] found that the resonances could not be described by the single level Breit-Wigner formula, and attributed this behavior to the fission component. The resonances in the measured fission cross section of $Pu^{241}$ in the 0.1–11 eV energy range have been found to be asymmetric. This has been attributed to interference effects in the present analysis of the fission data as well.

## EXPERIMENTAL METHOD

The fission cross section of $Pu^{241}$ was measured using the Materials Testing Reactor (MTR) fast chopper.[2] The fission events were detected by a gas scintillation detector.[3] The detector was divided into four chambers, each viewed by a 2-in. photomultipler tube. The walls of the chamber were coated with sodium salicilate and the face of the photomultiplier with *p*-quaterphenyl. Each chamber contained a 2- × 3-in. foil on which was deposited the fissile material (80.2% $Pu^{241}$ with contaminant of 8.2% $Pu^{239}$) by a painting and firing technique. Foils prepared in this manner had an average thickness of 0.1 mg/cm². No check of uniformity was made. The photomultiplier tubes were completely enclosed in the gas volume and electrical connections were made through a multi-lead Kovar seal. The signal was developed across an anode load of 400 Ω and fed directly to a back-biased diode with the bias set to eliminate the alpha particles. The scintillating gas was argon which was allowed to flow continuously through the counter. The number of neutrons per unit time which passed through the fission foil was measured by a pair of $BF_3$ proportional counters mounted behind the fission chamber. The data were taken at a flight path of 8.5 m at chopper rotor speeds of 400, 1500, and 3000 rpm with resolution of 3 μsec/m at 0.02 eV and 0.35 μsec/m at the highest energies. Pulses from the fission chamber and from the $BF_3$ counters were stored simultaneously in separate sections of a 1024 channel time-of-flight analyzer. An automatic time delay circuit between the fission detector and the $BF_3$ counter corrected for differences which existed in flight path between them.

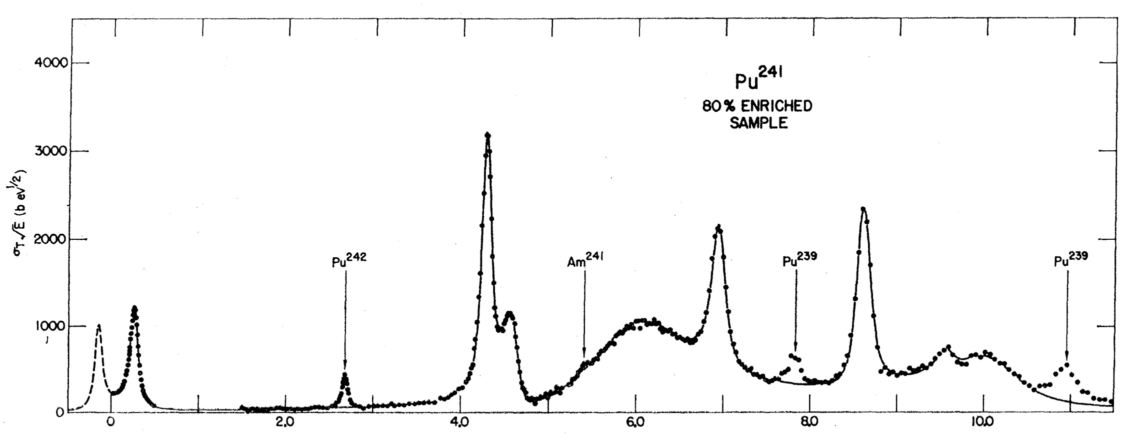


FIG. 1. The total cross section of $Pu^{241}$, multiplied by the square root of the neutron energy, as a function of neutron energy below 11 eV. The solid line shows the multilevel fit to the data.

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[3] C. Eggler and C. M. Huddleston, Nucleonics 14, 34 (1956).

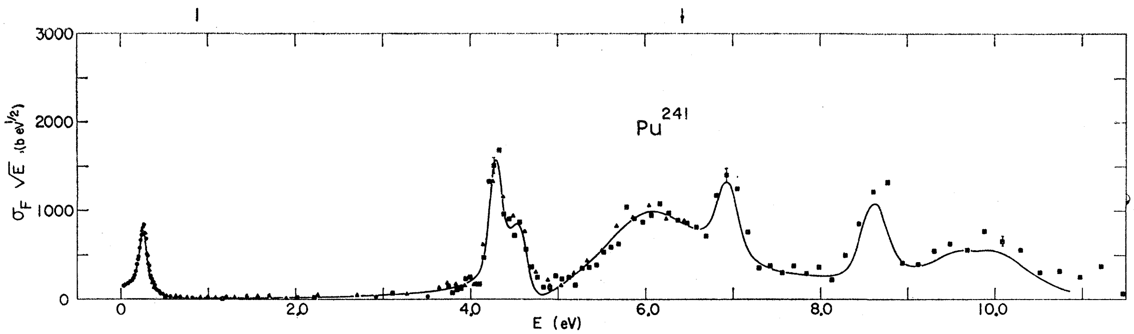


FIG. 2. The fission cross section of $Pu^{241}$, multiplied by the square root of the neutron energy, as a function of neutron energy below 11 eV. The solid line shows the multilevel fit to the data. The circles refer to 400-rpm data, the triangles to 1500-rpm data, and the squares to the 3000-rpm data

## DISCUSSION

To convert the relative cross section into absolute cross section, it is necessary to normalize some point in the data to a known absolute value. The normalization of the data was carried out at 6 eV using the total cross section of $Pu^{241}$ as the known value. From the shapes of the total and fission cross section curves shown in Figs. 1 and 2 it is evident that the broad 6-eV resonance is primarily due to fission. From the resonance parameters given by Simpson and Moore,[1] the scattering and radiative capture cross sections of $14\pm4$ and $14\pm7$ b, respectively, were calculated at 6 eV, using the multilevel formula. Subtracting the calculated value of $\sigma_s$ and $\sigma_c$ from the measured total cross section of $434\pm6$ b, one obtains a fission cross section of $406\pm10$ b. Since $\Gamma_f \gg \Gamma_\gamma$ at 6 eV, uncertainty in $\Gamma_\gamma$, and likewise in $\sigma_c$, will introduce relatively small error in the derived fission cross section at 6 eV. The measured fission data on $Pu^{241}$ were then normalized to the value of $406\pm10$ b at 6 eV. The normalization of the low energy data was made requiring the integral of $\sigma_f(t)dt$ from 1.5 eV to 100 eV to be equal for the 400-rpm and 3000-rpm runs. Corrections were made below 6 eV for the presence of the $Pu^{239}$ contaminant in all runs, subsequent to normalization.

Figure 1 shows the total cross section of $Pu^{241}$, as measured previously by Simpson and Schuman.[4] Figure 2 shows the fission cross section of $Pu^{241}$, measured as described above. The good agreement of the 1500-rpm data with the other runs tends to verify the normalization technique used to match the high and low resolution runs. The indicated error bars represent only counting statistics. The error in normalizing the low and high resolution data is estimated to be 2.5%. The solid line in both figures represents the multilevel fit to the data up to 11 eV using the parameters obtained by Simpson and Moore.[1] Appropriate resolution broadening corrections have been made. The agreement between the present data and the previous theoretical fit indicates that the assumptions made in the total cross section analysis of $Pu^{241}$ are substantially correct.

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[4] O. D. Simpson and R. P. Schuman, Nucl. Sci. Eng. 11, 111 (1961).