NEUTRON TRANSMISSION MEASUREMENTS AND RESONANCE PARAMETERS IN PL-240

O. D. Simpson and R. G. Fluharty

April 22, 1957

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NEUTRON TRANSMISSION MEASUREMENTS AND RESONANCE PARAMETERS IN PU-240

A ten minute paper to be presented at the Washington, D.C., meeting of the American Physical Society April 25, 26, and 27, 1957.

by

O. D. Simpson and R. G. Fluharty

ABSTRACT

Neutron transmission measurements for Pu-240 have been made with the Materials Testing Reactor fast chopper at resolutions of 0.04 to 0.50 μsec/meter. Since the highest purity sample available contained 20% Pu-239, it was necessary to make Pu-239 transmission measurements at corresponding resolutions to correct for the contamination. Resonances in Pu-240 have been found at the following energies: 1.06, 20.4, 38.2, 41.7, 66.2, 72.3, 89.6, 91.6, 104, 116, 119 ev. An average level spacing per spin state of 12 ± 2 ev was observed. Breit-Wigner parameters have been determined for resonances below 120 ev. The ratio $R_0/D$ for these resonances was $(2.0 \pm 0.6) \times 10^{-4}$. 
NEUTRON TRANSMISSION MEASUREMENTS AND RESONANCE PARAMETERS IN PU-240

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I. INTRODUCTION

Neutron transmission measurements for Pu-240 have been made with the Materials Testing Reactor fast chopper using a resolution of 0.04 to 0.50 μsec/meter, and resonance parameters have been studied up to 120 ev. Because of a twenty percent Pu-239 contaminant in the Pu-240 samples, transmissions were also measured for Pu-239. Accuracy above 120 ev is limited due to the Pu-239 contaminant.

The cross section of Pu-240 is of interest to the reactor people, since approximately four-tenths of all the neutrons absorbed in the fissionable material Pu-239 produce Pu-240. Parameters for a large 1.06 ev resonance have been measured by using several different sample thicknesses. Since appreciable time may be spent in this energy region by fission neutrons in the thermalization process, accurate information on this resonance is desirable.

The measurement of a material such as Pu-240 presents problems which are not usually encountered. Pu-240 decays by alpha emission (~5 mev) with a 6600 year half life; and is, therefore, of considerable hazard as a radioactive poison. This necessitates remote handling and well sealed sample containers. In addition, some question exists about the effect of the alpha radiation upon stability of the solution, but we have observed no complications at the concentrations we have used.
The samples which have been used for these measurements have resulted from the contributions of many people. The material was supplied by Mr. J. Martin of the Oak Ridge Isotopes Division, Dr. V. E. Pilcher, of Brookhaven National Laboratory, designed and supplied the dry oxide sample container, and Dr. John H. Cooper, of Oak Ridge National Laboratory, loaded the thick PuO₂ sample. Dr. W. McVey, of the Atomic Energy Division of Phillips Petroleum Company, prepared the DNO₃ solution samples. Many AEC and National Laboratory staff members have contributed their time in arranging for these samples.

SLIDE I

This slide shows the transmissions over the 1.06 ev resonance for the six different Pu-24O sample thicknesses, covering a sample thickness range of approximately 1500 to 1. The 0.0736 gm/cm² sample was produced by dissolving PuO₂ in a DNO₃-D₂O solution. The sample thickness was determined by mass measurement and by alpha counting. The two methods agreed within 3 percent. The 3.680 and 0.736 mg/cm² samples were made by diluting the 0.0736 gm/cm² sample solution by factors of 20 and 100 respectively. These samples should, therefore, be known to the same accuracy as the 0.0736 gm/cm² sample. The 1.1008 gm/cm² sample was prepared by packing PuO₂ powder into a special sample holder. The two lower transmission dips are observed in Pu-239 samples which have a 2.36 percent Pu-24O contaminant. These samples were used in the measurements to determine the Pu-239 effect in the other Pu-24O samples.

By assuming a partial width for gamma emission $\Gamma_{\gamma} = 0.030$ ev for
the 1.06 ev resonance, the reduced neutron widths $\Gamma_n^0$ obtained from five of the sample thicknesses all agreed to within 10 percent. A $\Gamma_n^0$ of 2.00 mv is observed, which corresponds to a peak cross section of $1.60 \times 10^5$ barns. This is in agreement with the measured peak cross section when corrected for Doppler effects. This means that the instrument resolution is small compared to the width of this level. The resonance absorption integral has been calculated from the parameters obtained from the first eleven levels and found to be $7282 \pm 747$ barns, with the 1.06 ev resonance contributing 97 percent of this value. Analysis of these data is continuing and an attempt will be made to obtain a value for $\Gamma_Y$.

**SLIDE 2**

This slide covers the energy region of approximately 5 to 13 ev. Even though our thickest Pu-240 sample (1.1008 gm/cm²) was used, no Pu-240 resonances were observed. Since no Pu-240 resonances were observed, the data should yield good resonance parameters for the Pu-239 resonances.

**SLIDE 3**

This slide covers the energy region from 13 to 25 volts and was taken with the 45 meter flight path. The thickest Pu-240 sample data shows one Pu-240 resonance appearing in this region at 20.4 ev. The effect of this resonance is also observed in the data taken with Pu-239 samples which have small Pu-240 contaminations. The analysis of this plus additional data taken at 16 meters for the different sample thicknesses yielded an average $\Gamma_n^0$ of 2.01 mv.
The next slide shows two more Pu-240 resonances which occur at 38.2 and 41.7 ev. The $\Gamma_n^0$ obtained for the 38.2 ev resonances was 2.25 mv. The 41.7 ev Pu-240 resonance is not resolved from the Pu-239 41.3 ev resonance, and a correction was necessary. The $\Gamma_n^0$ obtained for the 41.7 ev resonance was 0.29 mv. These were the only two Pu-240 resonances found in the region 25 to 60 ev.

The next slide shows seven more resonances due to Pu-240. Accuracy of these parameters was limited by the Pu-239 contamination in the samples. A highly enriched Pu-240 sample would be especially desirable in this region. Analysis of data above 120 ev is practically impossible to analyze because of the small level spacing in Pu-239. At 150 ev, the instrument resolution is approximately equal to the level spacing of Pu-240.

This is a table of the resonance energies, the neutron scattering widths, and the reduced neutron scattering widths with their errors. The large errors indicated result from the Pu-239 contaminant.

This slide shows the average level spacing per spin state of Pu-240 to be $12 \pm 2$ ev. Since only one spin state is possible, the level spacing per spin state is also equal to the average distance between levels.
The average value of the strength function $\bar{f}_n^0/D$ for Pu-240 was found to be $(2.0 \pm 0.6) \times 10^{-4}$. The straight line was drawn by applying a least square fit to the data points, which were weighted according to their accuracy.
SLIDE 1
TABLE I

Pu$^{240}$ Resonance Parameters

<table>
<thead>
<tr>
<th>$E_p$</th>
<th>$\Gamma_n$</th>
<th>$\Gamma_n^0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.06</td>
<td>2.06 ± 0.10</td>
<td>2.00 ± 0.10</td>
</tr>
<tr>
<td>20.4</td>
<td>2.44 ± 0.25</td>
<td>0.54 ± 0.06</td>
</tr>
<tr>
<td>38.2</td>
<td>13.9 ± 1.4</td>
<td>2.25 ± 0.23</td>
</tr>
<tr>
<td>41.7</td>
<td>1.87 ± 0.47</td>
<td>0.29 ± 0.07</td>
</tr>
<tr>
<td>66.2</td>
<td>45 ± 18</td>
<td>5.5 ± 2.2</td>
</tr>
<tr>
<td>72.3</td>
<td>29 ± 12</td>
<td>3.4 ± 1.4</td>
</tr>
<tr>
<td>89.6</td>
<td>17 ± 6</td>
<td>1.8 ± 0.6</td>
</tr>
<tr>
<td>91.6</td>
<td>4 ± 2</td>
<td>0.4 ± 0.2</td>
</tr>
<tr>
<td>104</td>
<td>62 ± 25</td>
<td>6.1 ± 2.5</td>
</tr>
<tr>
<td>116</td>
<td>21 ± 21</td>
<td>2.0 ± 2.0</td>
</tr>
<tr>
<td>119</td>
<td>47 ± 28</td>
<td>4.3 ± 2.6</td>
</tr>
</tbody>
</table>

An average $\Gamma_\gamma$ of 0.030 ev was assumed for each resonance.
Pu$^{240}$

$D = 12 \pm 2$ ev/SPIN STATE
Pu$^{240}$

\[
\frac{\Gamma_n^0}{D} = (2.0 \pm 0.6) \times 10^{-4}
\]