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SPONTANEOUS-FISSION NEUTRONS OF CALIFORNIA-252 AND CURIUM-244

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Radiation Laboratory, Department of Physics
University of California, Berkeley, California
March 14, 1955

Further measurements of the multiplicities of prompt neutrons from the spontaneous fission of Cf$^{252}$ and Cm$^{244}$ have been made in a large cadmium-loaded scintillator. $^1$ The electronics have been improved and more cadmium has been added. The moderated neutrons are now captured with a mean life of 10 microseconds and the pulses are photographed from an oscilloscope sweep 30 microseconds long. Using the average number of neutrons per spontaneous fission of Cf$^{252}$, $\bar{v} = 3.53 \pm 0.15$ (probable errors shown throughout), $^2$ we found the efficiency for detecting one neutron to be $\epsilon = 0.772 \pm 0.034$. The ratio $\bar{v}$ Cf$^{252}$ / $\bar{v}$ Cm$^{244} = 1.35 \pm 0.01$ has been obtained, giving $\bar{v}$ Cm$^{244} = 2.62 \pm 0.11$. Higgins et al. $^3$ have measured $\bar{v}$ Cm$^{244} = 2.60 \pm 0.12$.

If $F(n)$ is the observed multiplicity distribution, the true distribution, $P(v)$, is obtained from

$$P(v) = \sum_{n=0}^{\text{max}} \frac{n!}{v!(n-v)!} \epsilon^{-n}(1-\epsilon)^{n-v}.$$

The observed numbers of fissions of each nuclide giving $v$ neutrons are shown in Table I. Also given are the value of $P(v)$ (normalized so that $\sum_v P(v) = 1$) obtained after correcting the data for backgrounds of 0.0052 and 0.0084 neutron per fission for the Cf$^{252}$ and Cm$^{244}$ respectively.

<table>
<thead>
<tr>
<th>$v$</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cm$^{244}$</td>
<td>Observed</td>
<td>999</td>
<td>4259</td>
<td>5814</td>
<td>3750</td>
<td>1174</td>
<td>188</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Cm$^{244}$</td>
<td>$P(v)$</td>
<td>$\pm 0.006 \pm 0.022 \pm 0.018 \pm 0.016 \pm 0.020 \pm 0.005 \pm 0.001$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cm$^{252}$</td>
<td>Observed</td>
<td>312</td>
<td>1922</td>
<td>4216</td>
<td>4612</td>
<td>2648</td>
<td>836</td>
<td>170</td>
<td>29</td>
</tr>
<tr>
<td>Cm$^{252}$</td>
<td>$P(v)$</td>
<td>$\pm 0.001 \pm 0.035 \pm 0.150 \pm 0.315 \pm 0.328 \pm 0.143 \pm 0.038 \pm 0.008 \pm 0.002$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The normalized value of $P(n)$ and $P(\nu)$ for Cm$^{244}$ and Cf$^{252}$ are shown in Fig. 1 and Fig. 2.

The average number of neutrons from the spontaneous fission of Pu$^{240}$ has been measured at Los Alamos. Preliminary results from a comparison of Cf$^{252}$ (3925 fissions) and Pu$^{240}$ (4610 fissions) indicate that the $\nu$'s for Cf$^{252}$ and Cm$^{244}$ used above to determine the efficiency are too low. Based on the $\nu$ for Pu$^{240}$, with a statistical error of 5 percent given, we obtain $\bar{\nu}$ Cf$^{252} = 4.01 \pm 0.14$ and $\bar{\nu}$ Cm$^{244} = 3.01 \pm 0.11$. Our efficiency for neutron detection would be reduced to $\varepsilon = 0.671 \pm 0.023$ and the calculated points of the multiplicity distributions shifted toward higher multiplicities. The multiplicity distributions based on $\varepsilon = 0.671$ are given in Table II. Measurements concerning this discrepancy are continuing.

Table II. Calculated neutron multiplicity distributions based on $\varepsilon = 0.671$.

<table>
<thead>
<tr>
<th>$\nu$</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cm$^{244}$</td>
<td>$-0.004 \pm 0.007$ &amp; $0.247 \pm 0.382$ &amp; $0.233 \pm 0.062$ &amp; $0.010$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$P(\nu)$</td>
<td>$-0.002 \pm 0.008$ &amp; $0.060 \pm 0.244$ &amp; $0.372 \pm 0.225$ &amp; $0.073 \pm 0.014 \pm 0.007$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cf$^{252}$</td>
<td>$-0.002 \pm 0.008$ &amp; $0.060 \pm 0.244$ &amp; $0.372 \pm 0.225$ &amp; $0.073 \pm 0.014 \pm 0.007$</td>
<td></td>
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</tbody>
</table>

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1. D. A. Hicks, J. Ise, Jr., and P. V. Pyle, Phys. Rev. 97, 564 (1955). The calculated multiplicity distribution given in this reference is incorrect because of an error in the published value of $\bar{\nu}$ Cf$^{252}$ (see reference 2).
LEGENDS FOR FIGURES

Fig. 1 Neutron number distribution arising from the spontaneous fission of Curium-244. Probable errors are shown.

Fig. 2 Neutron number distribution arising from the spontaneous fission of Californium-252. Probable errors are shown.
Fig. 1

RELATIVE NUMBER OF FISSIONS (NORMALIZED)

CALculated
"True" SPECTRUM

EXPERIMENTALLY

OBSERVED

SPECTRUM

NUMBER OF NEUTRONS PER FISSION