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SPONTANEOUS FISSION OF $^{234}$U, $^{236}$Pu, $^{240}$Gm, AND $^{244}$Gm

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In a recent communication commenting on the mechanism of fission we called attention to the simple exponential dependence of spontaneous fission rate on $Z^2/A$ and to the effect of an odd nucleon in slowing the fission process. Since it is of interest to test further the simple correlation of the spontaneous fission rate for even-even nuclides with $Z^2/A$, a further number of such rates have been determined.

The spontaneous fission rates were measured by placing the chemically purified samples on one electrode of a parallel plate ionization chamber, filled with a mixture of argon and carbon dioxide, which was connected with an amplifier followed by a register and a stylus recorder. The results are summarized in Table I.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Fissions/gm-hr</th>
<th>&quot;Half-life&quot; (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{234}U$</td>
<td>$13 \pm 6$</td>
<td>$2 \pm 1 \times 10^{16}$</td>
</tr>
<tr>
<td>$^{236}Pu$</td>
<td>$5.8 \pm 2 \times 10^7$</td>
<td>$3.5 \pm 1 \times 10^7$</td>
</tr>
<tr>
<td>$^{240}Cm$</td>
<td>$1.0 \pm 0.2 \times 10^{11}$</td>
<td>$1.9 \pm 0.4 \times 10^6$</td>
</tr>
<tr>
<td>$^{244}Cm$</td>
<td>$1.4 \pm 0.2 \times 10^{10}$</td>
<td>$1.4 \pm 0.2 \times 10^7$</td>
</tr>
</tbody>
</table>

*The errors indicated are statistical only and do not include any estimate for possible systematic errors.
The $^{234}$U was a sample of high isotopic purity obtained by the electromagnetic concentration process, the $^{236}$Pu was prepared by bombarding highly enriched $^{235}$U with 18 Mev deuterons according to the reactions

$$U^{235}(d,n)Np^{236} \rightarrow \beta^{-} Pu^{236},$$

the $^{240}$Cm came from the bombardment of $^{239}$Pu with 38 Mev helium ions according to the reaction $Pu^{239}(a,3n)Cm^{240}$, and the $^{241}$Cm came from the pile neutron bombardment of $Am^{243}$ (containing $Am^{241}$) by the reactions

$$Am^{243}(n,\gamma)Am^{244} \rightarrow Cm^{244}.$$

By the nature of their methods of production, the $^{240}$Cm and $^{241}$Cm contained some $^{242}$Cm whose spontaneous fission had to be subtracted from the total rate in each case. The $^{240}$Cm also contained some $^{241}$Cm, but since the fission rate seemed to decay with the half-life of $^{240}$Cm, the contribution of the $^{241}$Cm must have been small. This observation on $^{241}$Cm would agree with the lower rate expected for nuclides having odd nucleons. The result for $^{234}$U is consistent with the earlier observation of Segre $^2$ who reported an upper limit of 30 spontaneous fissions/gram-hour.

These data are included in Fig. 1 which is otherwise identical with the plot in the previous report$^1$(where references are given), with the exception that odd nucleon nuclides, which apparently all fall above the line, are not included. As can be seen, the new even-even nuclides fit in fairly well with the correlation. However, some even-even nuclides such as $^{234}$U, and possibly also $^{232}$U and $Th^{230}$, exhibit substantial deviations in the direction of slower rates. It is apparent
that more data are needed in order to establish the pattern for even-even nuclides in detail. Nevertheless, it can be definitely stated that the spontaneous fission rates for even-even nuclides seem to define a certain limiting rate, and it seems especially significant that the extrapolation of the line (in Fig. 1) representing this rate to the region of instantaneous rate (that is, half-life of the order of $10^{-20}$ seconds) gives a value of about 0.7 for $2^{2}/A$, which corresponds with the predicted limiting value for $2^{2}/A$.

Similar considerations in regard to spontaneous fission rates have recently been published by Whitehouse and Galbraith.\(^3\)

We wish to express our appreciation to Professor J. G. Hamilton, T. M. Putnam, Jr., G. B. Rossi, and the operating crew of the 60-inch cyclotron of the Crocker Laboratory for their help in the bombardments. We would also like to thank the Y-12 Area of the Oak Ridge National Laboratory for supplying the highly purified U\(^{234}\) sample. This work was performed under the auspices of the U. S. Atomic Energy Commission.

\(^1\)G. T. Seaborg, Phys. Rev. 85, 157 (1951).
\(^3\)W. J. Whitehouse and W. Galbraith, Nature 169, 494 (1952).
Fig. 1. Plot of spontaneous fission rates of even-even nuclides (* signifies lower limit to half-life).