$_{94}Pu^{240}$ and Its Spontaneous Fission*

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Measurements of spontaneous fission of $_{94}Pu^{239}$ show that neutron irradiation of this substance forms a body with a high spontaneous-fission rate. This substance is with practical certainty $_{94}Pu^{240}$ and has a spontaneous-fission rate of approximately 1.6×10^6 fissions/g hr. $_{94}Pu^{239}$ itself has a spontaneous-fission rate of the order of 40 fissions/g hr.

SPONTANEOUS fission of samples of element 94 has been under study for the last year, and it now seems desirable to give a short review of the present status of the experiments. It is to be understood that this is not a final report and many quantitative points are still under study, although the qualitative features are rather sure.

The significant experimental results are summarized in the following table which gives the spontaneous fission observed in various samples of element 94.

Sample	$94^{240}/94^{239}$	Counts	Fissions/g hr
*C*6	0.6×10^{-6}	8	40
*C*10	65×10^{-6}	131	180
*C*16	1000×10^{-6}	154	1580

Sample *C*6 is material produced by irradiation with the Berkeley cyclotron, *C*10 is material produced in the Oak Ridge pile, and *C*16 is material reirradiated at Oak Ridge. The third column gives the number of fissions observed on which the number of the fourth column is based. When samples *C*6 and *C*10 were observed, it was thought that the difference in the spontaneous-fission rate was significant, and the hypothesis was put forward in a discussion between E. Fermi and the writers that its increase may be due to 94^{240} having a very high spontaneous-fission rate and being present in different amounts in the two samples. In order to check this hypothesis, sample *C*16 of reirradiated material was investigated.

The figures in column two have been estimated with use of all available data upon the irradiation conditions and the following constants at thermal energies: $\sigma_f(94^{239})=664\times10^{-24}$ cm^2; $\sigma_r(U^{238})=2.8\times10^{-24}$; $\alpha(94^{239})=0.54$.[1] A correction was also made for resonance absorption in U^{238}, and a reasonable hypothesis for the neutron density along a string in the pile was used. It is felt, however, that this part of the data is the most uncertain one, errors of a factor 2 being possible.

The data of the table, however, fit very well with the assumption that 94^{239} has a spontaneous fission rate of 40 fissions/g hr and 94^{240} has a spontaneous fission rate of 1.6×10^6 fissions/g hr.

A discussion of the possibility that the observed spontaneous fission may be due to isotopes of uranium or 93 leads to untenable conclusions on the basis of the fact that slow-neutron irradiation of 94^{239} produces the highly-fissioning materials. Now the possible reactions conceivably, although not very probably, produced by slow neutrons are as follows:

(1) 94^{239} could go to U^{236} by an (n,α) reaction, but the spontaneous fission of U^{236} has been investigated by us and is at least 10 times too small, if present at all, to account for the observed fission rate of reirradiated 94^{239}.

(2) An (n,p) reaction would produce 93^{239}, a well-known substance with a period of 2.3 days. Our observations on spontaneous fission do not show any decay with such a period; and it is also known from the growth of 94^{239} or to 93^{239} that there is no long-lived isomeric state of 93^{239}. If we consider the possibility of elements 95 or 96 being responsible for the spontaneous fission we have the following difficulties: (a) 94^{239} by neutron capture should not give a beta emitter which could decay to 95 and 96. This fact would be very exceptional and against known semiempirical rules of nuclear systematics. (b) Experiments by R. Wilson using Edwin McMillan's recoil method have not shown the existence of a nonrecoiling beta activity of short life. (c) Long-lifed beta activities have been extracted from the reirradiated sample, at least to a great extent.

These points will be investigated also by chemical methods in cooperation with Mr. A. C. Wahl.

Note added in preparing the manuscript for publication: The spontaneous fission rate of Pu^{240} was subsequently measured at Los Alamos by the methods described by E. Segrè [Phys. Rev. **86**, 21 (1952)] and found to be 4.61×10^2 fissions/g sec based on 10^4 fissions observed. This number should be added to Table II of that paper.

* This paper is, with minor literary changes, a report dated September 8, 1944, of work done at the Los Alamos Scientific Laboratory of the University of California. It has recently been declassified.

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[1] α is the ratio of radiative-capture probability to fission probability when a neutron is absorbed.