UNIVERSITY OF CALIFORNIA — BERKELEY

UCRL- 1419

~~SECRET~~

DECLASSIFIED

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*

1946. The transfer of this document
contents in any manner to an unauthorized
person is prohibited.

RADIATION LABORATORY

UCRL-1419
CD

UNIVERSITY OF CALIFORNIA
Radiation Laboratory

~~RESTRICTED DATA~~

This document contains restricted data as defined in the Atomic Energy Act of 1946. Its transmittal or disclosure of its contents in any manner to an unauthorized person is prohibited.

INDEX NO. UCRL-1409
This document contains 9 pages
This is copy 74 of 99 series A

Issued to Information Division

Classification

[illegible]

~~SECRET~~

UCRL-1409
Physics-Fission

DECLASSIFIED

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

SOME COMMENTS ON THE MECHANISM OF FISSION

Glenn T. Seaborg

July 25, 1951

CLASSIFICATION CANCELLED
BY AUTHORITY OF THE DECLASSIFICATION
BRANCH USAEC *per TID 1116*
BY *B. Robert* *5-15-86*
SIGNATURE OF THE DATE
PERSON MAKING THE
CHANGE

~~RESTRICTED DATA~~

This document contains restricted data
as defined in the Atomic Energy Act of
1946. Its transmittal or disclosure of its
contents in any manner to an unauthorized
person is prohibited.

Berkeley, California

~~SECRET~~
-2-

UCRL-1409
Physics-Fission

DECLASSIFIED

Standard Distribution: Series A

Copy Numbers

Argonne National Laboratory	1 - 12
Armed Forces Special Weapons Project	13
Atomic Energy Commission, Washington	14 - 19
Brookhaven National Laboratory	20 - 23
Bureau of Ships	24
Carbide & Carbon Chemicals Company (K-25 Plant)	25 - 26
Carbide & Carbon Chemicals Company (Y-12 Area)	27 - 28
Chicago Patent Group	29
Chief of Naval Research	30
Columbia University (Havens)	31
duPont Company	32 - 35
General Electric Company, Richland	36 - 39
Hanford Operations Office	40
Idaho Operations Office	41 - 42
Iowa State College	43
Knolls Atomic Power Laboratory	44 - 47
Los Alamos	48 - 50
Mound Laboratory	51 - 52
National Advisory Committee for Aeronautics	53
Naval Research Laboratory	54
New York Operations Office	55 - 56
North American Aviation, Inc.	57 - 59
Oak Ridge National Laboratory (X-10)	60 - 67
Patent Branch, Washington	68
Savannah River Operations Office	69
UCLA Medical Research Laboratory (Warren)	70
USAF - Headquarters	71
U. S. Naval Radiological Defense Laboratory	72
University of California Radiation Laboratory	73 - 75
Westinghouse Electric Corporation	76 - 79
Wright-Patterson Air Force Base	80 - 82
Technical Information Service, Oak Ridge	83 - 97
Aircraft Nuclear Propulsion Project, Oak Ridge	98 - 99

Total 99

Information Division
Radiation Laboratory
University of California
Berkeley, California

~~DECLASSIFIED~~
~~SECRET~~

UCRL-1409

SOME COMMENTS ON THE MECHANISM OF FISSION

Glenn T. Seaborg
Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

July 25, 1951

ABSTRACT

A correlation of spontaneous fission rates with Z and A is made to show that these rates depend on the nuclear type. Some suggestions as to the mechanisms are given and it is also shown how these relate to the mechanism of slow neutron and photo fission.

SOME COMMENTS ON THE MECHANISM OF FISSION

Glenn T. Seaborg
Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

July 25, 1951

A number of spontaneous fission rates are now known and a study of the relation of these to Z and A should make it possible to come to a better understanding of this process which in turn should lead to a better understanding of the slow neutron fission mechanism as well. A number of spontaneous fission rates are summarized in Table 1.

Our attempts to correlate these rates with the existing theoretical expectations^{1,2} have not been successful and therefore it seems worthwhile to attempt to study the data from the point of view of finding their empirical relationship.

Figure 1 shows a plot of the logarithm of the "half-life" for spontaneous fission versus the fissionability parameter, Z^2/A , and leads to some very interesting conclusions. The points for the even-even nuclides, with some exceptions, seem to indicate that the rate for this nuclear type depends exponentially in a simple way on the parameter Z^2/A . It is tempting to assume that the rate of spontaneous fission is controlled by a Boltzmann type factor in which the required activation energy for fission depends on Z^2/A ; the form of the plot would suggest that this might be a linear dependence with a negative coefficient for Z^2/A . However, another type such as an inverse dependence of fission activation energy on Z^2/A also fits nearly as well over the range of data plotted. In any case it is interesting to note that extrapolation of the line in Figure 1 to the

Table 1

Summary of Spontaneous Fission Rates

Nuclide	Fissions/gram/hour	Half-life (years)	References
Th ²³⁰	≤ 1.4	$\geq 1.5 \times 10^{17}$	3
Th ²³²	0.15 1.2	1.4×10^{18} 1.7×10^{17}	3 4
Pa ²³¹	≤ 20	$\geq 10^{16}$	3
U ²³²	≤ 25000	$\geq 8 \times 10^{12}$	3
U ²³³	< 0.7	$> 3 \times 10^{17}$	3
U ²³⁴	< 30	$> 7 \times 10^{15}$	3
U ²³⁵	1.2	1.9×10^{17}	3
U ²³⁶	10 ± 8	$\sim 2 \times 10^{16}$	5
U ²³⁸	24.8 ± 0.9	8.0×10^{15}	6,3
Np ²³⁷	≤ 5	$\geq 4 \times 10^{16}$	3
Np ²³⁹	≤ 40000	$\geq 5 \times 10^{12}$	3
Pu ²³⁸	5.1×10^6 4.1×10^6	5.4×10^{10} 4.9×10^{10}	3 7
Pu ²³⁹	36	5.5×10^{15}	3
Pu ²⁴⁰	1.66×10^6	1.2×10^{11}	8
Am ²⁴¹	≤ 14000	$\geq 1.4 \times 10^{13}$	3
Cm ²⁴²	3×10^{10} 2.7×10^{10}	6.5×10^6 7.2×10^6	9 10
Cm ²⁴⁴	0.7×10^{10}	3×10^7	11

Fig. 1
 PLOT OF SPONTANEOUS FISSION RATES
 (⊖ signifies lower limit to half-life)

region of instantaneous rate of spontaneous fission (that is, half-life of order of 10^{-20} seconds) gives a value of about 47 for Z^2/A , which corresponds with the predicted limiting value¹ for Z^2/A .

The data seem also to indicate that on the average for a given value of Z^2/A , the rate is greater for an even-even nuclide than one with an odd number of nucleons. Since Z^2/A is a representation of Z^2/r^3 , where r is the nuclear radius, the slower rates for the odd-neutron nuclides may be related to their expected larger nuclei; on this basis the largest departure of an odd-nucleon nuclide from the line in Figure 1 corresponds to the order of one percent larger radius than for the "hypothetical" corresponding even-even nuclide. Thus the slower rates may result from the lower zero-point energy of the modes of vibration which lead to fission associated with the nuclei with the larger radii.

Similar considerations may be useful in interpreting some of the results from the study of slow neutron fission probabilities. The slow neutron fission probabilities of the even-even nuclides in the trans-uranium region seem to be lower than expected on the simple theory.¹ For example, a nucleus like Cm^{242} has a slow neutron fission cross section of less than 5 barns¹² in spite of the fact that the critical fission energy of the intermediate Cm^{243} is of the order of 4 Mev, much less than the estimated 6 Mev of neutron binding energy. It is possible that the time for fission is lengthened for such an odd-nucleon intermediate nucleus to the point where the (n, γ) reaction is able to compete more successfully than is the case for even-odd nuclides like U^{235} , Pu^{239} , etc., where the intermediate fissioning nuclei are of the even-even type.

The effect of an odd nucleon in slowing the fission process may also explain the photofission results of H. W. Koch, J. McElhinney, and E. L. Gasteiger¹³ who found, for example, higher effective energetic thresholds for U^{235} , U^{233} , and Pu^{239} than for U^{238} , contrary to expectations from existing theory.^{1,2}

It will be interesting to see whether even-even nuclei with abnormally small nuclear radii due to closed sub-shells will have especially high rates of spontaneous fission. Thus a nucleus such as 100^{248} which would have two closed sub-shells on the Mayer picture,¹⁴ 100 protons and 148 neutrons, might be expected to exhibit such an abnormally high rate. Similarly, the large slow neutron fission cross section¹² of a nuclide like Am^{242} might be connected with the sub-shell of 148 neutrons in the intermediate Am^{243} .

The above considerations may make it possible to predict with a fair degree of confidence, especially for the even-even nuclides, the spontaneous fission rates for undiscovered nuclides and hence make it possible to plan experiments more intelligently for their detection.

It is a pleasure to acknowledge helpful discussions with K. Street, Jr., A. Ghiorso, J. O. Rasmussen, and I. Perlman.

REFERENCES

1. N. Bohr and J. A. Wheeler, Phys. Rev. 56, 426 (1939).
2. S. Frankel and N. Metropolis, Phys. Rev. 72, 914 (1947).
3. O. Chamberlain, G. W. Farwell, J. Jungerman, E. Segrè, and C. E. Wiegand, quoted by E. Segrè in U. S. Atomic Energy Commission Declassified Document, LADC-975 (May 8, 1951).
4. H. Pose, Z. Physik 121, 293 (1943).
5. A. H. Jaffey and A. Hirsch, reported in Argonne National Laboratory Report, ANL-4326 (August 3, 1949).
6. G. Scharff-Goldhaber and G. S. Klaiber, Phys. Rev. 70, 229 (1946).
7. A. H. Jaffey and A. Hirsch, reported in Argonne National Laboratory Report, ANL-4286 (May 12, 1949).
8. G. W. Farwell, E. Segrè, A. Spane, and C. E. Wiegand, Los Alamos Scientific Laboratory Report, LA-490 (April 25, 1946).
9. A. Ghiorso and H. P. Robinson, reported in University of California Radiation Laboratory Progress Report, Chemistry Section, BC-84 (October 14, 1947).
10. G. C. Hanna, B. G. Harvey, N. Moss, and P. R. Tunncliffe, Phys. Rev. 81, 466 (1951).
11. A. E. Larsh, A. Ghiorso, and S. G. Thompson, reported in University of California Radiation Laboratory Report, UCRL-1365 (June 26, 1951).
12. G. C. Hanna, B. G. Harvey, N. Moss, and P. R. Tunncliffe, Phys. Rev. 81, 893 (1951).
13. H. W. Koch, J. McElhinney, and E. L. Gasteiger, Phys. Rev. 77, 329 (1950).
14. M. G. Mayer, Phys. Rev. 75, 1969 (1949).