

BNL-65300

CONF-981003 --

**Int. Conf. Physics of Nuclear Science and Technology**

**October 5-8, 1998**

**SPONTANEOUS FISSION HALF-LIVES  
AND THEIR SYSTEMATICS\***

Norman E. Holden  
Reactor Division  
Brookhaven National Lab  
Upton, New York, 11973

RECEIVED  
APR 08 1998  
OSTI

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED



MASTER

19980427 076

DTIC QUALITY INSPECTED 3

## **DISCLAIMER**

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## SUMMARY

Spontaneous fission is a phenomenon exhibited by heavy nuclei, which can be a major mode of decay of nuclei of elements heavier than thorium and can be a determining factor in their stability. For purposes of this paper, spontaneous fission will be considered a process in which a nucleus breaks up into two approximately equal parts. The emission of light nuclei or heavy ions<sup>1</sup> such as  $^{12}\text{C}$ ,  $^{16}\text{O}$ , or  $^{32}\text{S}$  will not be considered. This radioactive decay mode is often much smaller than the spontaneous fission decay mode, although this is not true in all cases<sup>2,3,4</sup>. Barwick<sup>2</sup> noted that this might indicate that the assumed half-life for spontaneous fission of some older experiments might be partially due to heavy fragment radioactivity. Other than taking note of this potential correction to spontaneous fission half-lives, this decay mode of heavy fragment radioactivity will be ignored. Excited states of some heavy nuclei may decay via spontaneous fission. These so-called fission isomers will not be discussed here<sup>5</sup>. Electron capture (EC) or beta-delayed fission is a process in which prompt fission of a sufficiently excited daughter state occurs following population by EC or beta decay. The fission activity will appear to decay with the half-life of the parent and was earlier confused in some cases with SF. This process has been discussed in detail in a review<sup>6</sup> and will not be considered in this paper.

## HALF-LIFE ANALYSIS

All of the various spontaneous fission experiments have been reanalyzed and recommended half-life values for 124 nuclei are available for elements from  $Z=82$  to  $Z=109$ <sup>7</sup>. If the alpha particle decay to spontaneous fission decay ratio has been measured, the spontaneous fission half-life has been revised based on the latest value of the total half-life of the nuclide<sup>8</sup>. The revised value may not agree with the value as reported by the author.

In cases, where it is possible to do so, the uncertainty is calculated from a weighted average of listed measurements using a variance weighting technique, either the reciprocal square of the author's reported uncertainty or that value as revised. Exceptions to the weighted average rule had to be made for many nuclides. In some cases, there was only one measurement and in other cases, a selected value was recommended, which was considered superior to the other listed measurements.

Examples of data revision are given in Tables I and II for  $^{246}\text{Cm}$  and  $^{252}\text{Cf}$ , respectively. Various measurements of the spontaneous fission half-life have been renormalized to the recommended total half-life, where the  $\alpha/\text{SF}$  value provides the spontaneous fission value.

## HALF-LIFE SYSTEMATICS

When the results of the re-evaluation of spontaneous fission half-lives are examined, the half-life values as a function of neutron

number, N, for the various even-even nuclei have a peak which moves smoothly from N=144 in uranium to N=146 in plutonium, to N=150 in curium and californium, to N=152 in fermium and nobelium, to N=158 in rutherfordium to N=160 in seaborgium. The suggestion that a closed subshell at N=152 might provide added stability against spontaneous fission for elements 100 and 102 disappears by element 104. Oganessian suggested<sup>9</sup> this was due to the decrease of the outer fission barrier of the double-humped curve below the groundstate. For nuclides with odd numbers of neutrons or protons and with both particles odd, there are fewer data available. Spontaneous fission rates in even-odd nuclei is smaller than adjacent even-even nuclei by from three to six orders of magnitude.

Table I Spontaneous Fission Half-life of <sup>246</sup>Cm

Reference Author/Year	Reported $T_{1/2}/10^7$ a	Revised $T_{1/2}/10^7$ a	Comments on Reference
Fields <sup>10</sup>	> 1.24	> 1.24	Estimated $\alpha/sf=2740\pm140$ ; not used
Fried <sup>11</sup>	2.0 $\pm$ 0.8	2.0 $\pm$ 0.8	Estimated mass, fission counting; not used
Metta <sup>12</sup>	1.66 $\pm$ 0.10	1.82 $\pm$ 0.01	2 $\pi$ chamber; $\alpha/sf=3822\pm10$
MacMurdo <sup>13</sup>	1.80 $\pm$ 0.01	1.83 $\pm$ 0.02	$\alpha/sf = 3833\pm32$

Table II Spontaneous Fission Half-life of <sup>252</sup>Cf

Reference Author/Year	Reported $T_{1/2}/a$	Revised $T_{1/2}/a$	Comments on Reference
Ghiorso <sup>14</sup>	$\approx$ 100.	114.	$\alpha/sf = 42$ ; not used
Diamond <sup>15</sup>	60. $\pm$ 12.	76. $\pm$ 15.	Photographic Plate; $\alpha/sf=29$
Magnusson <sup>16</sup>	66. $\pm$ 10.	82. $\pm$ 12.	Parallel Plate Ion Chamb. $\alpha/sf = 30\pm1$
Eastwood <sup>17</sup>	82. $\pm$ 6.	87.3 $\pm$ 6.1	Ion Chamber; $\alpha/sf = 32\pm2$
Sevier <sup>18</sup>	not given	99. $\pm$ 7.	photo emulsion; $\alpha/sf = 36.4\pm2.4$
Metta <sup>19</sup>	85.5 $\pm$ 0.5	85.5 $\pm$ 0.5	$\alpha/sf = 31.3\pm0.2$
Aleksandrov <sup>20</sup>	85.2 $\pm$ 0.4	85.6 $\pm$ 0.4	Si det.; $\alpha/sf=31.5, 31.1$
Pandey <sup>21</sup>	not given	86.2 $\pm$ 0.9	CR-39 solid state fission track det.; $\alpha/sf=31.56\pm0.35$

#### REFERENCES

1. H.J.Rose, G.A.Jones, Nature 307, 245 (1984).
2. S.W.Barwick, P.B.Price, J.D.Stevenson, Phys. Rev. C31, 1984 (1985).
3. A.Sandulescu, Yu.S.Zamyatnin, I.A.Lebedev, B.F.Myasoedov, S.P.Tret'yakova, D.Hasan, Izv. Akad. Nauk. SSSR, Ser. Fiz. 49,

- 2104 (1985).
4. S.Wang, P.B.Price, S.W.Barwick, K.J.Moody, E.K.Hulet, Phys.Rev. C36, 2717 (1987).
  5. D.N.Poenaru, M.S.Ivascu, D.Mazilu, Fission Isomers, p 41-61, Chapter 3, Vol.III, Fission and Beta-Delayed Modes, (1989) in Particle Emission from Nuclei, CRC Press, Inc.
  6. H.L.Hall, D.C.Hoffman, Annu. Rev. Nucl. Part. Sci. 43, 147 (1992).
  7. N.E.Holden, D.C.Hoffman, Pure and Appl. Chem. (to be published 1998).
  8. N.E.Holden, "Table of the Isotopes" in Handbook of Chemistry and Physics, 78th Edition, 1997-1998, pp 11-41 to 11-146 CRC Press, Inc.(1997) and updates.
  9. Yu.Ts.Organessian, A.G.Demin, A.S.Iljinov, S.P.Tretyakova, A.A.Pleve, Yu.E.Penionzhkevich, M.P.Ivanov, Yu.P.Tretyakov, Nucl. Phys. A239, 157 (1975).
  10. P.R.Fields, M.H.Studier, H.Diamond, J.F.Mech, M.G.Inghram, G.L.Pyle, C.M.Stevens, S.M.Fried, W.M.Manning, A.Ghiorso, S.G.Thompson, G.H.Higgins, G.T.Seaborg, Phys. Rev. 102, 180 (1956).
  11. S.M.Fried, G.L.Pyle, C.M.Stevens, J.R.Huizenga, J. Inorg. Nucl. Chem. 2, 415 (1956).
  12. D.H.Metta, H.Diamond, F.R.Kelly, J. Inorg. Nucl. Chem. 31, 1245 (1969).
  13. K.W.MacMurdo, R.M.Harbour, R.W.Benjamin, J. Inorg. Nucl. Chem. 33, 1241 (1971).
  14. A.Ghiorso, S.G.Thompson, G.R.Choppin, B.G.Harvey, Phys. Rev. 94, 1081 (1954).
  15. H.Diamond, L.B.Magnusson, J.F.Mech, C.M.Stevens, A.M.Friedman, M.H.Studier, P.R.Fields, J.R.Huizenga, Phys. Rev. 94, 1083 (1954).
  16. L.B.Magnusson, M.H.Studier, P.R.Fields, C.M.Stevens, J.F.Mech, A.M.Friedman, H.Diamond, J.R.Huizenga, Phys. Rev. 96, 1576 (1954).
  17. T.A.Eastwood, J.P.Butler, M.J.Cabell, H.G.Jackson, R.P.Schulman, F.M.Rourke, T.L.Collins, Phys. Rev. 107, 1635 (1957).
  18. K.D.Sevier, Nucl. Instrum. Methods 14, 318 (1961).
  19. D.Metta, H.Diamond, R.F.Barnes, J.Milsted, J.Gray, Jr., D.J.Henderson, C.M.Stevens, J. Inorg. Nucl. Chem. 27, 33 (1965).
  20. B.M.Aleksandrov, M.A.Bak, V.G.Bogdanov, S.S.Bugorkov, A.V.Drapchinskii, Z.I.Solov'eva, A.V.Sorokina, Sov. J. At. Energy 28, 462 (1970).
  21. A.K.Pandey, R.C.Sharma, P.C.Kalsi, R.H.Iyer, Nucl. Instrum. Methods B 82, 151 (1993).

\*Research was carried out under the auspices of the US Department of Energy (Contract DE-AC02-76CH00016)

M98004442



Report Number (14) BNL--65300  
CONF-981003--  
\_\_\_\_\_  
\_\_\_\_\_

Publ. Date (11) 199803  
Sponsor Code (18) DOE/ER, XF  
UC Category (19) UC-413, DOE/ER

DOE