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SPONTANEOUS FISSION HALF-LIVES FOR GROUND-STATE NUCLIDES

(Technical Report)

Prepared for publication by
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Spontaneous fission half-lives for ground-state nuclides*

(Technical Report)

Abstract: Measurements of the spontaneous fission half-lives of nuclides of elements $Z = 82$ through 109 have been compiled (cutoff date of April 1998) and evaluated. Recommended values are tabulated along with total half-lives.

INTRODUCTION

Spontaneous fission (SF), a phenomenon exhibited by heavy nuclei, was discovered over 50 years ago[a]. There is interest in spontaneous fission because it can be a major mode of decay of nuclei heavier than thorium and can be a determining factor in their stability and will ultimately limit the number of new chemical elements that can exist. It also provides the opportunity for studying the fission process with no added excitation energy, and is more sensitive than induced fission to shell effects and relatively small changes in nuclear structure in both the fissioning nucleus and the fission fragments. Although SF half-lives generally decrease with increasing atomic number, there is an overlapping of half-life values. There are also large hindrance factors associated with the decay of odd-neutron or odd-proton nuclei[b].

Other important modes of decay for heavy nuclei are alpha- and beta-particle decay and electron capture. In some of these nuclei, a decay mode called heavy fragment emission[c] can also occur. Where possible, corrections have been made for heavy fragment emission but it will not be considered further in this paper. In addition, excited states of some heavy nuclei may decay via spontaneous fission. These so-called fission isomers will not be discussed here[d]. 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 previous review[e] and will not be considered in this paper.

ANALYSIS

All of the various experiments have been reanalyzed, and recommended half-life values for spontaneous fission are presented (see Tables I to CXXV) for over 100 nuclei of elements that range from lead ($Z = 82$) through meitnerium ($Z = 109$). An attempt has been made to revise values based on the latest parameters. If the α-particle to spontaneous fission decay ratio has been measured, the spontaneous fission half-life is revised based on the latest value of the total half-life of that nuclide[f]; this may not agree with that 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 as revised. Exceptions to the weighted average rule had to be made for some nuclides.

In such cases, recommendations were made using either a selected value considered superior to other listed measurements, or a weighted average was calculated for each of the different experimental techniques used and an unweighted average of these half-lives was recommended. All tables indicate the particular method chosen. A summary of the recommended spontaneous fission and total half-lives is presented in Table CXXVI.

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DISCUSSION OF RESULTS

For ^{238}U, all measurements were performed and reported as specific activity for one gram of material. The results have been converted to half-lives to be consistent with recommendations for all other nuclides.

There is a special problem with the case of spontaneous fission in ^{238}U. The measurements of fission tracks in mica-uranium, lexan uranium sandwiches or in ordinary glass, which is not dated, have had problems. The half-life derived in these cases does not agree with the values derived from other techniques. The specific activity, in general, is lower, and the half-life is larger than for other techniques. There can be a number of reasons for the lower specific activity. These can include partial fission track fading, poor thermal neutron dosimetry, and dating of samples of known age with the external detector technique. Some details on the fission track fading problem, which was ignored in the first of the measurements in the 1960s, are that the fading can now be established from the reduced size of the etched tracks, but an unambiguous method for correcting the age reduction due to fading is not yet developed.

The determination of the ^{235}U reaction rate often involves dating work using pre-irradiated NBS-SRM glasses, which have poor dosimetry. In addition, the use of monitors other than Au or Co and failure to account for epithermal activation or neutron flux gradients in the irradiation facility are errors that can lead to incorrect values.

Finally, using external detectors can be unreliable due to significant differences in the track revelation efficiency between the mineral to be dated and the external detector used for registering the induced tracks. In most dating work, a determination of the track revelation efficiency is not carried out. As the detection efficiency of the external detector is commonly higher than that of the mineral to be dated, too low a spontaneous fission ^{238}U/^{235}U induced track density ratio will be measured, which needs to be compensated for by a lower ^{238}U specific activity to find the right age of the sample.

The result is that although the larger half-life value is probably consistent for use in dating minerals and other materials, it is not useful for determining the correct spontaneous fission half-life of ^{238}U for Table XI.

NOTE

Half-life units in decimal notation for the tables are μs = 10^{-6} seconds, ms = 10^{-3} seconds, s = seconds, min = minutes, h = hours, d = days and a = years.

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TEXT REFERENCES

a. K. A. Petrzhak, G. N. Flerov. *JETP (Sov. Phys.)* **10**, 1013 (1940).
b. D. C. Hoffman, M. R. Lane. *Radiochim. Acta* **70/71**, 135 (1995); D. C. Hoffman, T. M. Hamilton, M. R. Lane. "Spontaneous Fission", pp. 393–432, Chapter 10 in *Nuclear Decay Modes*, Institute of Physics Publishing, Bristol and Philadelphia (1996).
c. H. J. Rose, G. A. Jones. *Nature* **307**, 245 (1984); D. Hasegan, S. P. Tretyakova. *Particle Emission from Nuclei*, Vol II, Chap. 9, pp 234–257, CRC Press, Boca Raton, FL (1989).
d. 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, Boca Raton, FL (1989).
e. H. L. Hall, D. C. Hoffman. *Annu. Rev. Nucl. Part. Sci.* **43**, 147 (1992).

f. N. E. Holden. Table of the Isotopes in *CRC Handbook of Chemistry and Physics*, 79th ed. 1998–1999, section XI, pp. 41–149, (revised 1998) and revisions, CRC Press Inc., Boca Raton, FL (1998).

TABULATED RESULTS

Table I Spontaneous fission half-life of ^{208}Pb.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{19} a	Comments
Zakharova[1] (1995)	≥ 2	Mica track detectors
Recommended value	$t_{1/2} \geq 2 \times 10^{19}$ a	Selected value

Table II Spontaneous fission half-life of ^{230}Th.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{18} a	Comments
Segre[2] (1952)	> 0.15	Ionization chamber; not used
Tretyakova[3] (1985)	> 2.	Corrected for cluster decay
Recommended value	$t_{1/2} > 2 \times 10^{18}$ a	Selected value

Table III Spontaneous fission half-life of ^{232}Th.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{21} a	Comments
Segre[2] (1952)	> 0.0014	Ionization chamber
Podguskaya[4] (1955)	> 0.1	Ionization chamber
Flerov[5] (1958)	> 1.	Fission fragment proportional chamber
Spadavecchia[6] (1967)	> 1.0 ± 0.3	Rotating bubble chamber
Emma[7] (1975)	> 0.7	Mica-thorium sandwich
Bonetti[8] (1995)	1.22 ± 0.43	Nucl. track det. corrected cluster decay
Recommended value	$t_{1/2} = (1.2 \pm 0.4) \times 10^{21}$ a	Selected value

Table IV Spontaneous fission half-life of ^{231}Pa.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{17} a	Comments
Segre[2] (1952)	> 0.11	Ionization chamber; not used
Sandulescu[9] (1984)	> 2.	Fission fragment track detector
Recommended value	$t_{1/2} > 2 \times 10^{17}$ a	Selected value

Table V Spontaneous fission half-life of ^{230}U.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{10} a	Comments
Spadavecchia[6] (1967)	> 4.	Rotating bubble chamber
Recommended value	$t_{1/2} > 4 \times 10^{10}$ a	Selected value

Table VI Spontaneous fission half-life of ^{232}U.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{15} a	Comments
Jaffey[10] (1951)	0.08 ± 0.055	Unpublished; quoted by Hyde[10]
Segre[2] (1952)	> 0.008	Ionization chamber; not used
Bonetti[11] (1990)	> 6.84	Solid-state track detection; corrected cluster decay
Recommended value	$t_{1/2} > 6.8 \times 10^{15}$ a	Selected value

Table VII Spontaneous fission half-life of ^{233}U.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{17} a	Comments
Segre[2] (1952)	> 2.7	Ionization chamber
Aleksandrov[12] (1966)	1.2 ± 0.3	No mention of correction for ^{232}U. Just 0.03% of ^{232}U could account for the discrepancy with other measurements.
von Gunten[13] (1981)	> 2.7	97.11% enriched; rotating bubble chamber; corrected for the (α,n,f) reaction
Recommended value	$t_{1/2} > 2.7 \times 10^{17}$ a	Selected value

Table VIII Spontaneous fission half-life of ^{234}U.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{16} a	Comments
Segre[2] (1952)	> 0.6	Ionization chamber; not used
Ghiorso[14] (1952)	1.6 ± 0.7	Revised value; ionization chamber; not used
von Gunten[13] (1981)	1.42 ± 0.08	99.36% enriched; rotating bubble chamber; corrected for the (α,n,f) reaction
Wang[15] (1987)	1.9 ± 0.15	99.84% enriched; phosphate glass detector; ^{232}U corrected for; revised uncertainty by 50% for overestimate of zenith angle of fission fragments
Recommended value	$t_{1/2} = (1.5 \pm 0.2) \times 10^{16}$ a	Weighted average

Table IX Spontaneous fission half-life of ^{235}U.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{18} a	Comments
Segre[2] (1952)	0.18	Ionization chamber; not used
Aleksandrov[12] (1966)	0.35 ± 0.09	Fission track detectors; not used
Grütter[16] (1973)	> 1.8	Rotating bubble chamber; no corrections; not used
von Gunten[13] (1981)	9.8 ± 2.8	99.76% enriched; rotating bubble chamber; corrected for the (α,n,f) reaction
Recommended value	$t_{1/2} = (1.0 \pm 0.3) \times 10^{19}$ a	Selected value

Table X Spontaneous fission half-life of ^{236}U.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{16} a	Comments
Jaffey[17] (1949)	2. ± 1.6	Unpublished; quoted by Hyde[17]
Conde[18] (1971)	2.7 ± 0.3	$\lambda(^{238}U) / \lambda(^{236}U) = 0.30 \pm 0.03$
von Gunten[13] (1981)	2.43 ± 0.13	99.68% enriched; rotating bubble chamber; corrected for the (α,n,f) reaction
Belenky[19] (1983)	2.7 ± 0.4	Multiple neutron coincidence
Recommended value	$t_{1/2} = (2.5 \pm 0.1) \times 10^{16}$ a	Weighted average

Table XI Spontaneous fission half-life of ^{238}U.

Reference Author (Year)	As Reported / (10^{-17} a^{-1}) Specific Activity	Comments
Whitehouse[20] (1950)	8.38 ± 0.52	Ionization chamber
Segre[2] (1952)	8.60 ± 0.29	Ionization chamber
Fleischer[21] (1964)	6.85 ± 0.20	Mica-uranium sandwich; not used
Roberts[22] (1968)	7.03 ± 0.11	Mica-uranium sandwich; not used
Spadavecchia[6] (1967)	8.42 ± 0.10	Rotating bubble chamber
von Gunten[23] (1969)	8.66 ± 0.22	Fission products from ^{238}U
Galliker[24] (1970)	8.46 ± 0.06	Rotating bubble chamber
Storzer[25] (1970)	8.49 ± 0.76	Fission tracks in dated uranium glass
Kleeman[26] (1971)	6.8 ± 0.6	Lexan-uranium sandwich; not used
Thury[27] (1971)	8.66 ± 0.43	Third order coincidence
Leme[28] (1971)	7.30 ± 0.16	Mica-uranium sandwich; not used
Khan[29] (1973)	6.82 ± 0.55	Mica-uranium sandwich; not used
Ivanov[30] (1975)	7.12 ± 0.32	Mica-uranium sandwich; not used
Emma[7] (1975)	7.2 ± 0.2	Mica-uranium sandwich; not used
Wagner[31] (1975)	8.7 ± 0.6	Fission tracks in dated uranium glass
Thiel[32] (1976)	8.57 ± 0.42	Fission tracks in dated uranium glass
Kase[33] (1978)	8.22 ± 0.20	Ionization chamber
Popeko[34] (1980)	7.9 ± 0.4	Multiple neutron coincidence
Spaggiari[35] (1980)	9.26 ± 0.17	Mica-uranium sandwich; not used
Baptista[36] (1981)	6.6 ± 0.2	Mica-uranium sandwich; not used
Hadler[37] (1981)	8.6 ± 0.4	Mica-uranium sandwich; not used
de Carvalho[38] (1982)	11.8 ± 0.7	Fission tracks in ordinary glass; not used
Belenky[19] (1983)	8.35 ± 0.40	Multiple neutron coincidence
Vartanian[39] (1984)	8.23 ± 0.43	Fission tracks (plastic, uranium foils); not used
Ivanov[40] (1985)	8.29 ± 0.27	Double ionization chamber
Liu[41] (1991)	7.03 ± 0.21	Solid-state track detectors; not used
Recommended half-life value	$t_{1/2} = (8.2 \pm 0.1) \times 10^{15}$ a	Unweighted average of techniques

Table XII Spontaneous fission half-life of ^{237}Np.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{18} a	Comments
Druin[42] (1961)	> 1.	Nuclear photographic emulsion
Recommended value	$t_{1/2} > 1 \times 10^{18}$ a	Selected value

Table XIII Spontaneous fission half-life of ^{236}Pu.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^9 a	Comments
Ghiorso[14] (1952)	3.4 ± 1.2	Revised value; ionization chamber; not used
Selickij[43] (1988)	2.09 ± 0.06	Two sources; fragment detection in 2π geometry
Ogloblin[44] (1990)	1.36 ± 0.20	Solid-state track detector; reported by Hussonnois[45]
Hussonnois[45] (1995)	1.13 ± 0.1	Solid-state track detector; corrected cluster decay
Recommended value	$t_{1/2} = (1.5 \pm 0.3) \times 10^9$ a	Unweighted average value

Table XIV Spontaneous fission half-life of ^{238}Pu.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{10} a	Comments
Segre[2] (1952)	3.8	Revised value; ionization chamber; not used
Jaffey[46] (1949)	4.7 ± 0.6	Revised value;
Druin[42] (1961)	5.1 ± 0.6	Revised value; nuclear photographic emulsions
Hastings[47] (1972)	4.77 ± 0.14	$\lambda_\alpha / \lambda_f = 5.43 \times 10^8$; silicon surface barrier detectors
Gay[48] (1975)	4.63 ± 0.12	Fission fragment coincidences in mica
Selickij[43] (1988)	5.01 ± 0.21	4 sources; fragment detection in 2π geometry
Recommended value	$t_{1/2} = (4.75 \pm 0.09) \times 10^{10}$ a	Weighted average

Table XV Spontaneous fission half-life of ^{239}Pu.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{15} a	Comments
Segre[2] (1952)	5.5	Ionization chamber; not used
Druzhinin[49] (1985)	7.8 ± 1.6	$\lambda_f / \lambda_\alpha = 3.1 \pm 0.6 \times 10^{-12}$
Recommended value	$t_{1/2} = (8. \pm 2.) \times 10^{15}$ a	Selected value

Table XVI Spontaneous fission half-life of ^{240}Pu.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{11} a	Comments
Kindermann[50] (1953)	1.314 ± 0.026	Low geometry α counting; not used
Barclay[51] (1954)	1.225 ± 0.030	Low geometry α counting; not used
Chamberlain[52] (1954)	1.20	Low geometry α counting; not used
Mikheev[53] (1959)	1.20	α counting; gas scintillator; not used
Watt[54] (1962)	1.34 ± 0.015	Low geometry α counting; not used
Malkin[55] (1963)	1.45 ± 0.02	α counting; gas scintillator; not used
White[56] (1967)	1.27 ± 0.05	No details available; not used
Fieldhouse[57] (1967)	1.176 ± 0.025	Revised; spont. fiss. neutron emission rates
Budtz-Jorgensen[58] (1980)	1.15 ± 0.03	Fragment spectra; ionization chamber
Androsenko[59] (1984)	1.15 ± 0.03	Spontaneous fission neutron emission rates
Selickij[43] (1988)	1.17 ± 0.03	2 sources; fragment detection in 2π geometry
Dytlewski[60] (1989)	1.12 ± 0.02	Neut.coincid. + low α geometry counting
Ivanov[61] (1991)	1.15 ± 0.02	$\lambda_f / \lambda_\alpha$ in two ^{240}Pu standards
Recommended value	$t_{1/2} = (1.14 \pm 0.01) \times 10^{11}$ a	Weighted average

Table XVII Spontaneous fission half-life of ^{241}Pu.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{16} a	Comments
Druzhinin[49] (1985)	< 6.	$\lambda_\alpha / \lambda_f \approx 10^{11}$
Recommended value	$t_{1/2} < 6. \times 10^{16}$ a	Selected value

Table XVIII Spontaneous fission half-life of ^{242}Pu.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{10} a	Comments
Studier[62] (1956)	6.7 ± 0.7	Quoted by Mech[62]
Butler[63] (1956)	6.65 ± 0.10	$\lambda_\alpha / \lambda_f$, rel. total $t_{1/2} = 3.73 \times 10^5$ a
Mech[62] (1956)	6.79 ± 0.19	Revised value for $t_{1/2}(\alpha)$ of ^{242}Pu
Druin[42] (1961)	6.6 ± 0.7	gas scintillator; relative to $t_{1/2}(\alpha)$ of ^{238}Pu
Malkin[55] (1963)	7.45 ± 0.17	gas scintillator; specific activity
Meadows[64] (1977)	6.74 ± 0.05	$\lambda_\alpha / \lambda_f$ rel. total $t_{1/2}$ (^{239}Pu) = 24 290. a
Khan[65] (1980)	7.43	Mica fission track detector; not used
Selickij[43] (1988)	6.86 ± 0.26	Fission fragment detection in 2π geometry
Recommended value	$t_{1/2} = (6.77 \pm 0.07) \times 10^{10}$ a	Weighted average

Table XIX Spontaneous fission half-life of ^{244}Pu.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{10} a	Comments
Fields[66] (1955)	2.5 ± 0.8	Ionization chamber; not used
Fields[67] (1966)	6.67 ± 0.32	Revised value
Gokhberg[68] (1977)	6.8 ± 0.8	No details
Khan[65] (1980)	7.32	Fission track detector; not used
Moore[69] (1982)	6.56 ± 0.30	Ionization chamber; α counting; α spectrometry
Recommended value	$t_{1/2} = (6.6 \pm 0.2) \times 10^{10}$ a	Weighted average

Table XX Spontaneous fission half-life of ^{241}Am.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{14} a	Comments
Segre[2] (1952)	> 0.14	Ionization chamber; not used
Mikheev[53] (1960)	> 2.	Gas scintillator; not used
Druin[70] (1961)	2.3 ± 0.8	Gas scintillator
Galliker[24] (1970)	0.90 ± 0.04	Rotating bubble chamber
Gold[71] (1970)	1.147 ± 0.024	Mica fission track detector
Paul[72] (1986)	1.8 ± 0.4	Mica fission track detector
Moody[73] (1987)	0.64	Phosphate glass track detector
Kukushkin[74] (1993)	1.2 ± 0.6	Xe gas scintillator
Recommended value	$t_{1/2} = (1.2 \pm 0.3) \times 10^{14}$ a	Unweighted average of techniques

Table XXI Spontaneous fission half-life of ^{242m}Am.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{12} a	Comments
Caldwell[75] (1967)	1.0 ± 0.4	Revised; neut./fiss. frag. coincidence; not used
Zelenkov[76] (1986)	> 3.0	Silicon surface barrier detectors; $\lambda_f / \lambda_\alpha < 10^{-8}$
Recommended value	$t_{1/2} > 3. \times 10^{12}$ a	Selected value

Table XXII Spontaneous fission half-life of ^{243}Am.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{14} a	Comments
Aleksandrov[77] (1966)	> 0.33 ± 0.03	Glass fission track detector
Gvozdev[78] (1966)	2. ± 0.5	Glass fission track detector
Recommended value	$t_{1/2} = (2. \pm 0.5) \times 10^{14}$ a	Selected value

Table XXIII Spontaneous fission half-life of ^{240}Cm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{6} a	Comments
Ghiorso[14] (1952)	1.9 ± 0.4	Ionization chamber
Recommended value	$t_{1/2} = (1.9 \pm 0.4) \times 10^{6}$ a	Selected value

Table XXIV Spontaneous fission half-life of ^{242}Cm.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{6} a	Comments
Hanna[79] (1951)	7.2 ± 0.2	Fission fragment counting, ionization chamber
Armani[80] (1967)	6.82 ± 0.18	Revised value; Li-I fission neutron counting
Zhang[81] (1979)	7.46 ± 0.06	Mica fission track detector
Raghuraman[82] (1982)	7.15 ± 0.15	Solid state track detector
Umezawa[83] (1982)	6.89 ± 0.17	Mica fiss track det.; not used see Usuda
Zelenkov[76] (1986)	6.98 ± 0.33	Revised value; $\lambda_f / \lambda_\alpha = (6.4 \pm 0.3) \times 10^{-8}$ Silicon surface barrier detectors
Usuda[84] (1989)	6.96 ± 0.18	Mica fission track detector
Recommended value	$t_{1/2} = (7.0 \pm 0.2) \times 10^{6}$ a	Selected value; uncertainty covers the range of the most recent measurements

Table XXV Spontaneous fission half-life of ^{243}Cm.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^{11} a	Comments
Polynov[85] (1987)	5.5 ± 0.9	Mica fission track detector
Recommended value	$t_{1/2} = (5.5 \pm 0.9) \times 10^{11}$ a	Selected value

Table XXVI Spontaneous fission half-life of ^{244}Cm.

Reference Author (Year)	As Revised $t_{1/2}$ / 10^7 a	Comments
Ghiorso[14] (1952)	1.39 ± 0.20	Revised value; ionization chamber
Malkin[86] (1963)	1.46 ± 0.05	Gas scintillator
Metta[87] (1965)	1.346 ± 0.006	$\lambda_\alpha / \lambda_f = (7.43 \pm 0.01) \times 10^5$
Armani[80] (1967)	1.33 ± 0.03	Li-I fission neutron counter
Barton[88] (1970)	1.250 ± 0.007	Low geometry fission fragment counting
Hastings[89] (1972)	1.343 ± 0.006	Silicon surface barrier detector; $\lambda_\alpha / \lambda_f$, rel. $t_{1/2}$ (total) = 18.099 a
Pandey[90] (1990)	1.263 ± 0.025	CR-39 fission track detector; $\lambda_\alpha / \lambda_f = 6.98 \times 10^5$
Recommended value	$t_{1/2} = (1.32 \pm 0.02) \times 10^7$ a	Weighted average

Table XXVII Spontaneous fission half-life of ^{245}Cm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{12} a	Comments
Druzhinin[91] (1985)	1.4 ± 0.2	$\lambda_\alpha / \lambda_f$ ratio
Recommended value	$t_{1/2} = (1.4 \pm 0.2) \times 10^{12}$ a	Selected value

Table XXVIII Spontaneous fission half-life of ^{246}Cm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^7 a	Comments
Fields[92] (1956)	> 1.24	Estimated from $\lambda_\alpha / \lambda_f$ ratio; not used
Fried[93] (1956)	2.0 ± 0.8	fission counting; estimated mass; not used
Metta[94] (1969)	1.80 ± 0.01	2π chamber, semi-conductor; $\lambda_\alpha / \lambda_f = 3822 \pm 10$
MacMurdo[95] (1971)	1.85 ± 0.02	$\lambda_\alpha / \lambda_f = 3833 \pm 32$
Recommended value	$t_{1/2} = (1.81 \pm 0.02) \times 10^7$ a	Weighted average

Table XXIX Spontaneous fission half-life of ^{248}Cm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^6 a	Comments
Butler[96] (1956)	4.6 ± 0.5	specific fission activity; not used
Metta[94] (1969)	4.22 ± 0.12	2π chamber, semi-conductor; $\lambda_\alpha / \lambda_f = 11.0 \pm 0.3$
MacMurdo[95] (1971)	4.20 ± 0.05	Relative activity to ^{244}Cm
McCracken[97] (1971)	4.115 ± 0.034	Specific fission activity; ionization chamber
Recommended value	$t_{1/2} = (4.15 \pm 0.03) \times 10^6$ a	Weighted average

Table XXX Spontaneous fission half-life of ^{250}Cm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^4 a	Comments
Huizenga[98] (1957)	2.3	Estimated value; not used
CRG[99] (1966)	1.74 ± 0.24	Preliminary "Par" bomb shot results; not used
Metta[100] (1967)	1.13 ± 0.05	Ionization chamber; "Par" bomb shot results
Recommended value	$t_{1/2} = (1.13 \pm 0.05) \times 10^4$ a	Selected value

Table XXXI Spontaneous fission half-life of ^{249}Bk.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^9 a	Comments
Magnusson[101] (1954)	> 0.2	Ion chamber; $\lambda_\beta / \lambda_f = 3.78 \times 10^8$; not used
Diamond[102] (1954)	> 0.01	Ionization chamber; not used
Ghiorso[103] (1956)	0.6	Unpublished; quoted by Hyde[103]; not used
Eastwood[104] (1957)	> 1.4	Ionization chamber; not used
Milsted[105] (1969)	1.87 ± 0.09	Parallel plate ion chamber
Vorotnikov[106] (1970)	1.65 ± 0.17	Fission fragment glass detector
Recommended value	$t_{1/2} = (1.8 \pm 0.1) \times 10^9$ a	Weighted average

Table XXXII Spontaneous fission half-life of ^{237}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Lazarev[107] (1995)	≈ 21.	$\lambda_f / \lambda_{tot} \approx 0.1$; $t_{1/2} = 2.1 \pm 0.3$ s
Recommended value	$t_{1/2} \approx 21.$ s	Selected value

Table XXXIII Spontaneous fission half-life of ^{238}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Lazarev[107] (1995)	21. ± 2.	$\lambda_f / \lambda_{tot} \approx 1.$
Recommended value	$t_{1/2} = 21. \pm 2.$ ms	Selected value

Table XXXIV Spontaneous fission half-life of ^{240}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Lazarev[107] (1995)	≈ 53.	$\lambda_f / \lambda_{tot} \approx 0.02$; $t_{1/2} = 1.06 \pm 0.15$ min
Recommended value	$t_{1/2} \approx 53.$ min	Selected value

Table XXXV Spontaneous fission half-life of ^{242}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Lazarev[107] (1995)	≥ 17.4	$\lambda_f / \lambda_{tot} \leq 0.00014$; $t_{1/2} = 3.5$ min
Recommended value	$t_{1/2} \geq 17.$ d	Selected value

Table XXXVI Spontaneous fission half-life of ^{246}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^3 a	Comments
Hulet[108] (1953)	2.1 ± 0.3	$\lambda_\alpha / \lambda_f = 5.2 \times 10^5$
Friedman[109] (1963)	1.34 ± 0.16	Ion chamber; $\lambda_\alpha / \lambda_f = 3.3 \times 10^5$
Skobelev[110] (1968)	2.0 ± 0.2	Au-Si det.; $\lambda_\alpha / \lambda_f = 4.9 \times 10^5$
Recommended value	$t_{1/2} = (1.8 \pm 0.6) \times 10^3$ a	Weighted average

Table XXXVII Spontaneous fission half-life of ^{248}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^4 a	Comments
Hulet[111] (1954)	0.9	$\lambda_\alpha / \lambda_f \approx 10^4$
Perelygin[112] (1964)	3.4 ± 1.5	Ion chamber; quoted by Skobelev[110]
Skobelev[110] (1968)	4.1 ± 0.4	Mica det.; $\lambda_\alpha / \lambda_f = 4.3 \times 10^4$
Hulet[113] (1973)	3.2 ± 0.3	$\lambda_\alpha / \lambda_f = 3.5 \times 10^4$
Recommended value	$t_{1/2} = (3.2 \pm 0.3) \times 10^4$ a	Selected value

Table XXXVIII Spontaneous fission half-life of ^{249}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^{10} a	Comments
Magnusson[101] (1954)	≥ 0.0005	$\lambda_\alpha / \lambda_f \geq 1.2 \times 10^4$
Diamond[102] (1954)	> 0.0001	Ionization chamber
Ghiorso[103] (1956)	> 0.15	Unpublished; quoted by Hyde[103]
Eastwood[104] (1957)	> 0.045	Ionization chamber; $\lambda_\alpha / \lambda_f > 1.3 \times 10^6$
Milsted[105] (1969)	6.87 ± 0.33	Parallel plate ion chamber; $\lambda_\alpha / \lambda_f = 2 \times 10^8$
Vorotnikov[106] (1969)	> 0.2	Ionization chamber
Tarantin[114] (1987)	8.5 ± 0.5	Lavson + mica det.
Recommended value	$t_{1/2} = (8.\pm 1.) \times 10^{10}$ a	Selected value

Table XXXIX Spontaneous fission half-life of ^{250}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^4 a	Comments
Ghiorso[115] (1954)	0.5	$\lambda_\alpha / \lambda_f = 400$; not used
Diamond[102] (1954)	> 1.4	Revised
Magnusson[101] (1954)	1.9 ± 0.6	Parallel plate ion chamber; $\lambda_\alpha / \lambda_f = 1460 \pm 350$
Phillips[116] (1963)	1.73 ± 0.06	prop.ctr. $\lambda_\alpha / \lambda_f = 1330 \pm 45$
Metta[87] (1965)	1.66 ± 0.08	$\lambda_\alpha / \lambda_f = 1260 \pm 40$
Recommended value	$t_{1/2} = (1.7 \pm 0.1) \times 10^4$ a	Selected value

Table XL Spontaneous fission half-life of ^{252}Cf.

Reference Author (Year)	As Reported $t_{1/2}$ / a	Comments
Ghiorso[115] (1954)	100.	$\lambda_\alpha / \lambda_f = 42.$; not used
Diamond[102] (1954)	75. ± 15.	Revised
Magnusson[101] (1954)	79. ± 10.	Parallel plate ion chamber; $\lambda_\alpha / \lambda_f = 30 \pm 1$
Eastwood[104] (1957)	82. ± 6.	Ionization chamber; $\lambda_\alpha / \lambda_f = 32. \pm 2.$
Sevier[117] (1961)	98.9	Revised ; $\lambda_\alpha / \lambda_f = 36.45$
Metta[87] (1965)	85.5 ± 0.5	$\lambda_\alpha / \lambda_f = 31.3 \pm 0.2$
Aleksandrov[118] (1970)	85.6 ± 0.4	Si det.; $\lambda_\alpha / \lambda_f = 31.5, 31.1$
Pandey[90] (1993)	86.2 ± 0.9	CR-39 fission track detector; $\lambda_\alpha / \lambda_f = 31.56$
Recommended value	$t_{1/2} = (86. \pm 1.)$ a	Weighted average

Table XLI Spontaneous fission half-life of ^{254}Cf.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / d	Comments
Harvey[119] (1955)	85. ± 15.	No detectable α emission
Fields[92] (1956)	55.	No α or β emission
Bentley[120] (1956)	60. ± 10.	No details
Huizenga[98] (1957)	60.5 ± 1.1	Ion chamber; rev. Metta[87]; $\lambda_f / \lambda_{tot}$ from Bemis[121]
Phillips[116] (1963)	60.7 ± 0.2	Corr. for ^{250}Cf; rev. $\lambda_f / \lambda_{tot}$ from Bemis[121]
Metta[87] (1965)	62.1 ± 1.1	Ion Chamber; rev. $\lambda_f / \lambda_{tot}$ from Bemis[121]
Recommended value	$t_{1/2}$ = (60.9 ± 0.9) d	Weighted average

Table XLII Spontaneous fission half-life of ^{256}Cf.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / min	Comments
Hoffman[122] (1980)	12.3 ± 1.2	Ion chamber
Recommended value	$t_{1/2}$ = (12. ± 1.) min	Selected value

Table XLIII Spontaneous fission half-life of ^{253}Es.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / 10^5 a	Comments
Fields[123] (1954)	> 1.	No details; not used
Jones[124] (1956)	7. ± 3.	Ion chamber
Metta[87] (1965)	6.3 ± 0.2	$\lambda_\alpha / \lambda_f = 1.15 \pm 0.03 \times 10^7$
Recommended value	$t_{1/2} = (6.3 \pm 0.2) \times 10^5$ a	Weighted average

Table XLIV Spontaneous fission half-life of ^{254}Es.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / 10^7 a	Comments
Ghiorso[103] (1955)	0.015	Unpublished; quoted by Hyde[103]
McHarris[125] (1965)	0.068	Ionization chamber; quoted by Fields[126]
Fields[126] (1967)	> 2.5	Ion chamber; $\lambda_f / \lambda_\alpha < 3 \times 10^{-8}$
Recommended value	$t_{1/2} > 2.5 \times 10^7$ a	Selected value

Table XLV Spontaneous fission half-life of ^{254m}Es.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / a	Comments
Fields[123] (1954)	> 10.	$\lambda_f / \lambda_{tot} < 0.00045$
Recommended value	$t_{1/2}$ > 10. a	Selected value

Table XLVI Spontaneous fission half-life of ^{255}Es.

Reference	As Reported	
Author (Year)	$t_{1/2}$ / 10^3 a	Comments
Fields[126] (1967)	2.63 ± 0.14	Ion chamber; $\lambda_\beta / \lambda_f = 2.22 \pm 0.10 \times 10^4$
Recommended value	$t_{1/2} = (2.6 \pm 0.1) \times 10^3$ a	Selected value

Table XLVII Spontaneous fission half-life of ^{242}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Ter-Akopyan[127] (1975)	0.8 ± 0.2	$\lambda_f / \lambda_{tot} > 0.96$
Recommended value	$t_{1/2}$ = 0.8 ± 0.2 ms	Selected value

Table XLVIII Spontaneous fission half-life of ^{243}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ter-Akopyan[127] (1975)	≥ 50.	Estimated from excitation function systematics
Recommended value	$t_{1/2} \geq 50.$ s	Selected value

Table XLIX Spontaneous fission half-life of ^{244}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Nurmia[128] (1967)	3.3 ± 0.5	Spontaneous fission assumed
Ter-Akopyan[127] (1975)	4.	$\lambda_f / \lambda_{tot} > 0.97$
Recommended value	$t_{1/2}$ = 3.3 ± 0.5 ms	Selected value

Table L Spontaneous fission half-life of ^{245}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Ter-Akopyan[127] (1975)	> 1.1	Estimated from excitation function systematics
Recommended value	$t_{1/2}$ > 1.1 h	Selected value

Table LI Spontaneous fission half-life of ^{246}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Nurmia[128] (1967)	15. ± 5.	Mica det., $\lambda_f / \lambda_{tot}$ = 0.08;
Druin[129] (1971)	27. ± 8.	Solid-state det., $\lambda_f / \lambda_{tot}$ = 0.045 ± 0.013;
Ninov[130] (1996)	8. ± 3.	$\lambda_f / \lambda_{tot}$ = 0.15 ± 0.05
Recommended value	$t_{1/2}$ = 8. ± 3. s	Selected value

Table LII Spontaneous fission half-life of ^{248}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Nurmia[128] (1967)	10. ± 5.	Mica det.; $\lambda_f / \lambda_{tot}$ = 0.0010 ± 0.0005
Druin[129] (1971)	≈ 53.	Solid-state det.; $\lambda_\alpha / \lambda_f \approx 6000$
Recommended value	$t_{1/2}$ = 10. ± 5. h	Selected value

Table LIII Spontaneous fission half-life of ^{250}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / a	Comments
Druin[129] (1971)	≈ 9.5	Solid-state det.; $\lambda_f / \lambda_\alpha = 6 \times 10^{-6}$
Lazarev[131] (1989)	0.83 ± 0.15	$\lambda_f / \lambda_{tot} = (6.9 \pm 1.0) \times 10^{-5}$
Recommended value	$t_{1/2}$ = 0.8 ± 0.2 a	Selected value

Table LIV Spontaneous fission half-life of ^{250m}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / a	Comments
Lazarev[131] (1989)	≥ 0.07	$\lambda_f / \lambda_{tot} \geq 8.2 \times 10^{-7}$
Recommended value	$t_{1/2} \geq 0.07$ a	Selected value

Table LV Spontaneous fission half-life of ^{252}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / a	Comments
Friedman[132] (1956)	> 8.2	No details; not used
AHEG[133] (1966)	115. ± 60.	No details; not used
Ahmad[134] (1984)	125. ± 8.	$\lambda_f / \lambda_\alpha = (2.3 \pm 0.2) \times 10^{-5}$
Recommended value	$t_{1/2}$ = 125. ± 8. a	Selected value

Table LVI Spontaneous fission half-life of ^{254}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Fields[123] (1954)	220. ± 40.	Ionization chamber
Choppin[135] (1954)	≈ 135.	$\lambda_\alpha / \lambda_f \approx 10^3$
Choppin[136] (1955)	209.	$\lambda_\alpha / \lambda_f = 1550$
Jones[124] (1956)	246.	Ion Chamber
Fields[126] (1967)	228. ± 1.	4π counter $\lambda_\alpha / \lambda_f = 1695 \pm 8$ Si barrier det. $\lambda_\alpha / \lambda_f = 1664 \pm 17$
Recommended value	$t_{1/2}$ = 228. ± 1. d	Selected value

Table LVII Spontaneous fission half-life of ^{255}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^4 a	Comments
Phillips[116] (1963)	1.0 ± 0.4	Windowless prop. counter; $\lambda_f / \lambda_{tot} = (2.4 \pm 1.0) \times 10^{-7}$
Recommended value	$t_{1/2} = (1.0 \pm 0.4) \times 10^4$ a	Selected value

Table LVIII Spontaneous fission half-life of ^{256}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Choppin[136] (1955)	180. to 240.	$\lambda_\alpha / \lambda_f$ estimated to be 0.04
Phillips[137] (1958)	160. ± 10.	Windowless prop. counter
Sikkeland[138] (1965)	167. ± 6.	$\lambda_\alpha / \lambda_{\alpha+f} = 0.028 \pm 0.01$
Hoff[139] (1968)	171. ± 2.	Ion Chamber; $\lambda_\alpha / \lambda_{\alpha+f} = 0.081 \pm 0.003$
Recommended value	$t_{1/2}$ = 2.9 ± 0.1 h	Selected value

Table LIX Spontaneous fission half-life of ^{257}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / a	Comments
Hulet[140] (1964)	100. ± 20.	$\lambda_\alpha / \lambda_f = 468. \pm 100.$
Sikkeland[138] (1965)	≈ 131.	$\lambda_\alpha / \lambda_f = 600.$
CRG[99] (1966)	129. ± 45.	$\lambda_\alpha / \lambda_f = 500. \pm 175.$
Wild[141] (1973)	131. ± 3.	$\lambda_\alpha / \lambda_f = 475. \pm 10.$
Recommended value	$t_{1/2}$ = 131. ± 3. a	Weighted average

Table LX Spontaneous fission half-life of ^{258}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Hulet[142] (1971)	380. ± 60.	Fission tracks in mica; 3 standard deviation
Hulet[143] (1986)	360. ± 20.	Time correlation meas.; 1 standard deviation
Recommended value	$t_{1/2}$ = 0.37 ± 0.02 ms	Weighted average

Table LXI Spontaneous fission half-life of ^{259}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Hulet[144] (1980)	1.5 ± 0.3	$\lambda_f / \lambda_{tot} = 1.0$
Hoffman[145] (1981)	1.5 ± 0.2	$\lambda_f / \lambda_{tot} = 1.0$
Somerville[146] (1985)	1.6 ± 0.1	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2}$ = 1.5 ± 0.2 s	Selected value

Table LXII Spontaneous fission half-life of ^{260}Fm.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Lougheed[147] (1992)	≈ 4.	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2}$ ≈ 4. ms	Selected value

Table LXIII Spontaneous fission half-life of ^{245}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Ninov[130] (1996)	0.90 ± 0.25	12 fission events
Recommended value	$t_{1/2}$ = 0.9 ± 0.3 ms	Selected value

Table LXIV Spontaneous fission half-life of ^{247}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Hofmann[148] (1994)	0.23 (+ 0.19 / - 0.12)	2 fission events
Recommended value	$t_{1/2} \approx 0.2$ s	Selected value

Table LXV Spontaneous fission half-life of ^{248}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Gangrsky[149] (1980)	≥ 3.9	$\lambda_f / \lambda_{tot} \leq 0.0005$
Recommended value	$t_{1/2} \geq 3.9$ h	Selected value

Table LXVI Spontaneous fission half-life of ^{255}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Hoff[150] (1971)	≥ 12.5	$\lambda_f / \lambda_{tot} \leq 0.0015$; $t_{1/2} = 27.$ min.
Recommended value	$t_{1/2} \geq 12.5$ d	Selected value

Table LXVII Spontaneous fission half-life of ^{256}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Hoff[150] (1971)	> 1.9	$\lambda_f / \lambda_{tot} < 0.028$
Recommended value	$t_{1/2} > 1.9$ d	Selected value

Table LXVIII. Spontaneous fission half-life of ^{257}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Sikkeland[138] (1965)	> 2.9	$\lambda_f / \lambda_{tot} < 0.077$
Hoff[150] (1971)	> 6.1	$\lambda_f / \lambda_{tot} < 0.036$
Moody[151] (1993)	≥ 23.	$\lambda_f / \lambda_{tot} \leq 0.010$
Recommended value	$t_{1/2} \geq 23.$ d	Selected value

Table LXIX Spontaneous fission half-life of ^{258}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / 10^3 a	Comments
Lougheed[152] (1986)	> 0.41	Erroneously reported 1.5×10^5 days as years.
Moody[151] (1993)	≥ 4.7	$\lambda_f / \lambda_{tot} \leq 0.00003$
Recommended value	$t_{1/2} \geq 4.7 \times 10^3$ a	Selected value

Table LXX Spontaneous fission half-life of ^{258m}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Moody[151] (1993)	≥ 190.	$\lambda_f / \lambda_{tot} \leq 0.30$
Recommended value	$t_{1/2} \geq 190.$ min	Selected value

Table LXXI Spontaneous fission half-life of ^{259}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Wild[153] (1982)	< 106. ± 12.	$\lambda_f / \lambda_{tot} > 0.97$, $t_{1/2} = 103.$ min.
Moody[151] (1993)	< 97.3 ± 3.6	$\lambda_f / \lambda_{tot} > 0.987$; $t_{1/2} = 96.0$ min.
Recommended value	$t_{1/2} < 1.62 \pm 0.06$ h	Selected value

Table LXXII Spontaneous fission half-life of ^{260}Md.

Reference Author (Year)	As Reported $t_{1/2}$ / d	Comments
Hulet[154] (1986)	45.4 ± 0.7	$\lambda_f / \lambda_{tot} \approx 0.70$
Lougheed[147] (1992)	27.8 – 38.1	$\lambda_f / \lambda_{tot} > 0.73$
Recommended value	$t_{1/2} \approx 27.8 - 38.1$ d	Selected value

Table LXXIII Spontaneous fission half-life of ^{250}No.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Ter-Akopyan[127] (1975)	0.25 ± 0.05	$\lambda_f / \lambda_{tot} \approx 1.0$
Recommended value	$t_{1/2} = 0.25 \pm 0.05$ ms	Selected value

Table LXXIV Spontaneous fission half-life of ^{251}No.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ter-Akopyan[127] (1975)	≥ 10.	$\lambda_f / \lambda_{tot} \geq 0.08$
Recommended value	$t_{1/2} \geq 10.$ s	Selected value

Table LXXV Spontaneous fission half-life of ^{252}No.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ghiorso[155] (1967)	4.9 ± 0.6	$\lambda_f / \lambda_{tot} = 0.50$; revised total $t_{1/2}$, Wild[158]; not used
Bemis[156] (1977)	9. ± 1.	$\lambda_f / \lambda_{tot} = (0.27 \pm 0.02)$; revised total $t_{1/2}$, Wild[158]
Andreyev[157] (1993)	11. ± 3.	$\lambda_f / \lambda_{tot} = (0.216 \pm 0.042)$; revised total $t_{1/2}$, Wild[158]
Recommended value	$t_{1/2} = 9. \pm 1.$ s	Weighted average

Table LXXVI Spontaneous fission half-life of ^{254}No.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Flerov[159] (1967)	> 26.	$\lambda_f / \lambda_{tot} < 0.0006$
Somerville[146] (1985)	> 30.6	$\lambda_f / \lambda_{tot} < 0.0005$
Türler[160] (1988)	6.1 ± 5.6	$\lambda_f / \lambda_{tot} = 0.0025$
Lazarev[131] (1989)	8.9 ± 2.5	$\lambda_f / \lambda_{tot} = (0.0017 \pm 0.0005)$
Wild[158] (1994)	8.7 ± 3.3	$\lambda_f / \lambda_{tot} = (0.0017 \pm 0.0002)$; total $t_{1/2}$= 53. ± 20. s
Recommended value	$t_{1/2}$ = 8. ± 2. h	Weighted average

Table LXXVII Spontaneous fission half-life of ^{254m}No.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Lazarev[131] (1989)	≥ 140.	$\lambda_f / \lambda_{tot} \leq 0.002$
Recommended value	$t_{1/2} \geq$ 2.3 min	Selected value

Table LXXVIII Spontaneous fission half-life of ^{256}No.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Ghiorso[155] (1967)	19.3 ± 3.3	$\lambda_f / \lambda_{tot} = 0.0025$; $t_{1/2}$ = 2.9 s
Flerov[161] (1968)	≈ 9.7	$\lambda_f / \lambda_{tot} = 0.0050$; $t_{1/2}$ = 2.9 s
Hoffman[162] (1990)	9.2 (+ 0.7 / – 1.2)	$\lambda_f / \lambda_{tot} = 0.0053$; $t_{1/2}$ = 2.9 s
Recommended value	$t_{1/2}$ = 9. ± 1. min	Weighted average

Table LXXIX Spontaneous fission half-life of ^{257}No.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Lazarev[163] (1996)	> 28.	$\lambda_f / \lambda_{tot} = 0.015$; $t_{1/2}$ = 25 ± 4 s
Recommended value	$t_{1/2}$ > 28. min	Selected value

Table LXXX Spontaneous fission half-life of ^{258}No.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Nurmia[164] (1969)	≈ 1.2	$\lambda_f / \lambda_{tot} = 1.0$
Hulet[165] (1989)	1.2 ± 0.2	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2}$ = 1.2 ± 0.2 ms	Selected value

Table LXXXI Spontaneous fission half-life of ^{259}No.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Wild[153] (1982)	> 10.	$\lambda_f / \lambda_{tot} < 0.1$
Recommended value	$t_{1/2}$ > 10. h	Selected value

Table LXXXII Spontaneous fission half-life of ^{260}No.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Somerville[146] (1985)	106. ± 8.	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2}$ = 106. ± 8. ms	Selected value

Table LXXXIII Spontaneous fission half-life of ^{262}No.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Lougheed[166] (1988)	≈ 5.	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2} \approx 5$. ms	Selected value

Table LXXXIV Spontaneous fission half-life of ^{252}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[167] (1976)	≥ 100.	$\lambda_f / \lambda_{tot} \leq 0.01$
Recommended value	$t_{1/2} \geq 100$. s	Selected value

Table LXXXV Spontaneous fission half-life of ^{253}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[167] (1976)	≥ 130.	$\lambda_f / \lambda_{tot} \leq 0.01$
Hessberger[168] (1985)	> 7.	$\lambda_f / \lambda_{tot} < 0.20$
Recommended value	$t_{1/2} \geq 2.2$ min	Selected value

Table LXXXVI Spontaneous fission half-life of ^{254}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Oganessian[167] (1976)	≥ 3.6	$\lambda_f / \lambda_{tot} \leq 0.001$; Total $t_{1/2}$, Hessberger[168]
Recommended value	$t_{1/2} \geq 3.6$ h	Selected value

Table LXXXVII Spontaneous fission half-life of ^{255}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / h	Comments
Oganessian[167] (1976)	≥ 6.	$\lambda_f / \lambda_{tot} \leq 0.001$; $t_{1/2}$ = 22 s. Eskola[169]
Recommended value	$t_{1/2} \geq 6$. h	Selected value

Table LXXXVIII Spontaneous fission half-life of ^{256}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[170] (1970)	$\geq 8.4 \times 10^4$	Excitation function syst.; $\lambda_f / \lambda_{tot} < 0.00033$
Recommended value	$t_{1/2} \geq 1$. d	Selected value

Table LXXXIX Spontaneous fission half-life of ^{257}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[170] (1970)	$\geq 2 \times 10^3$	Excitation function syst.; $\lambda_f / \lambda_{tot} < 0.00033$
Recommended value	$t_{1/2} \geq 0.55$ h	Selected value

Table XC Spontaneous fission half-life of ^{258}Lr

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[171] (1971)	> 20.	If $t_{1/2}$ (^{258}No) < 20 seconds
Gregorich[172] (1992)	> 78.	$\lambda_f / \lambda_{tot} < 0.05$
Recommended value	$t_{1/2} > 78.$ s	Selected value

Table XCI Spontaneous fission half-life of ^{259}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Gregorich[172] (1992)	28. ± 3.	$\lambda_f / \lambda_{tot} = (0.23 \pm 0.02)$
Hamilton[173] (1992)	31. ± 4.	$\lambda_f / \lambda_\alpha = 0.25 \pm 0.03$; $\lambda_f / \lambda_{tot} = (0.20 \pm 0.02)$
Recommended value	$t_{1/2} = 31. \pm 4.$ s	Selected value

Table XCII Spontaneous fission half-life of ^{261}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Lougheed[174] (1987)	39. ± 12.	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2} = 39. \pm 12.$ min	Selected value

Table XCIII Spontaneous fission half-life of ^{262}Lr.

Reference Author (Year)	As Reported $t_{1/2}$ / min	Comments
Lougheed[174] (1987)	2160. ± 150.	$\lambda_f / \lambda_{tot} < 0.10$
Recommended value	$t_{1/2} > 1.5$ d	Selected value

Table XCIV Spontaneous fission half-life of ^{253}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[175] (1976)	$\approx 3.6 \times 10^6$	$\lambda_f / \lambda_{tot} \approx 0.50$
Hessberger[176] (1997)	48. (+ 17. / – 10.)	$\lambda_f / \lambda_{tot} \approx 1.0$
Recommended value	$t_{1/2} \approx 48.$ s	Selected value

Table XCV Spontaneous fission half-life of ^{254}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[177] (1975)	< 3000.	Production not detected
Ter-Akopyan[127] (1975)	500. ± 200.	$\lambda_f / \lambda_\alpha > 8.$
Hessberger[176] (1997)	23. ± 3.	$\lambda_f / \lambda_{tot} > 0.985$
Recommended value	$t_{1/2}$ = 23. ± 3. s	Selected value

Table XCVI Spontaneous fission half-life of ^{255}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[170] (1970)	≈ 4.	$\lambda_f / \lambda_{tot} \approx 0.5$, not used
Oganessian[177] (1975)	≈ 8.	$\lambda_f / \lambda_{tot} \approx 0.5$, $t_{1/2}$ = 4 s; not used
Münzenberg[178] (1981)	3.1 ± 1.3	$\lambda_f / \lambda_{tot} = 0.45$, not used
Oganessian[179] (1984)	3.4 ± 0.4	$\lambda_f / \lambda_{tot} = 0.5$, $t_{1/2}$ = 1.7 s; not used
Hessberger[180] (1985)	2.7 ± 0.5	$\lambda_f / \lambda_{tot} = 0.52 \pm 0.07$; $t_{1/2}$ = 1.4 s.
Hessberger[176] (1997)	3.1 ± 0.4	$\lambda_f / \lambda_{tot} = 0.45 \pm 0.06$; $t_{1/2}$ = 1.4 s.
Recommended value	$t_{1/2}$ = 2.9 ± 0.4 s	Weighted average

Table XCVII Spontaneous fission half-life of ^{256}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Oganessian[177] (1975)	5.	$\lambda_f / \lambda_{tot} \approx 1.0$; not used
Oganessian[179] (1984)	6.7 ± 0.2	$\lambda_f / \lambda_{tot} = 0.99$; not used
Hessberger[180] (1985)	7.4 ± 0.8	$\lambda_f / \lambda_{tot} = 0.978$; not used
Wild[158] (1994)	6.6 ± 1.1	Kinetic energy distribution study
Hessberger[176] (1997)	6.2 ± 0.2	$\lambda_f / \lambda_{tot} = 0.9968$
Recommended value	$t_{1/2}$ = 6.2 ± 0.2 ms	Weighted average

Table XCVIII Spontaneous fission half-life of ^{257}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[181] (1984)	≈ 39.	$\lambda_f / \lambda_{tot} \approx 0.12$; $t_{1/2}$= 4.7 s.
Somerville[146] (1985)	34. ± 22.	$\lambda_f / \lambda_{tot} = 0.14 \pm 0.09$
Münzenberg[178] (1981)	59. ± 37.	$\lambda_f / \lambda_{tot} = 0.08 \pm 0.05$
Hessberger[180] (1985)	> 134.	$\lambda_f / \lambda_{tot} < 0.035$
Bemis[182] (1988)	196. ± 25.	$\lambda_f / \lambda_{tot} = 0.024 \pm 0.003$
Hessberger[176] (1997)	> 336.	$\lambda_f / \lambda_{tot} < 0.014$
Recommended value	$t_{1/2}$ > 5.6 min	Selected value

Table XCIX Spontaneous fission half-life of ^{258}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Ghiorso[183] (1969)	13. ± 2.	$\lambda_f / \lambda_{tot} \approx 0.87$, Oganessian[167]
Somerville[146] (1985)	15. ± 3.	$\lambda_f / \lambda_{tot} \approx 0.87$, Oganessian[167]
Wild[158] (1994)	14. ± 2.	Kinetic energy distribution study
Recommended value	$t_{1/2}$ = 14. ± 2. ms	Weighted average

Table C Spontaneous fission half-life of ^{259}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Druin[184] (1973)	≈ 46.	$\lambda_f / \lambda_\alpha \approx 0.07$
Bemis[185] (1981)	48. ± 35.	$\lambda_f / \lambda_{tot} = 0.063 \pm 0.037$
Somerville[146] (1985)	38. ± 23.	$\lambda_f / \lambda_{tot} = 0.09 \pm 0.03$
Recommended value	$t_{1/2}$ = 0.7 ± 0.4 min	Selected value

Table CI Spontaneous fission half-life of ^{260}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Flerov[186] (1964)	300. ± 100.	Excitation function systematics
Oganessian[187] (1970)	100. ± 50.	Excitation function systematics
Druin[188] (1976)	80. ± 20.	Excitation function systematics
Druin[189] (1977)	76. ± 8.	Excitation function systematics
Nitschke[190] (1981)	23. ± 2.	Excitation function systematics
Somerville[146] (1985)	20.1 ± 0.7	Excitation function systematics
Hulet[165] (1989)	25.6 ± 7.	Excitation function systematics
Recommended value	$t_{1/2}$ = 20. ± 1. ms	Selected value

Table CII Spontaneous fission half-life of ^{261}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ghiorso[191] (1970)	≥ 650.	$\lambda_f / \lambda_{tot} \leq 0.10$
Kadkhodayan[192] (1996)	≥ 591.	$\lambda_f / \lambda_{tot} \leq 0.11$
Recommended value	$t_{1/2} \geq$ 11. min	Selected value

Table CIII Spontaneous fission half-life of ^{262}Rf.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Somerville[146] (1985)	0.047 ± 0.005	$\lambda_f / \lambda_{tot} = 1.0$
Lazarev[193] (1994)	1.2 (+ 1.0 / – 0.5)	^{266}Sg(α) - SF coincidence
Lane[194] (1996)	2.1 ± 0.2	$\lambda_f / \lambda_{tot} > 0.992$
Recommended value	$t_{1/2}$ = 2.1 ± 0.2 s	Selected value

Table CIV Spontaneous fission half-life of ^{255}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[195] (1976)	≈ 8.	$\lambda_f / \lambda_{tot} \approx 0.20$
Recommended value	$t_{1/2} \approx$ 8. s	Selected value

Table CV Spontaneous fission half-life of ^{256}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[196] (1983)	≥ 6.5	$\lambda_f / \lambda_{tot} \leq 0.40$
Recommended value	$t_{1/2} \geq 6.5$ s	Selected value

Table CVI Spontaneous fission half-life of ^{257}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[167] (1976)	≈ 25.	$\lambda_f / \lambda_{tot} \approx 0.20$, $t_{1/2} = 5.$ s
Hessberger[168] (1985)	8.2 ± 6.1	$\lambda_f / \lambda_{tot} = 0.17 \pm 0.11$
Recommended value	$t_{1/2} = 8. \pm 6.$ s	Selected value

Table CVII Spontaneous fission half-life ^{258}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Hessberger[168] (1985)	≥ 13.	$\lambda_f / \lambda_{tot} \leq 0.33 + (0.09 / - 0.05)$, Hessberger[176]
Recommended value	$t_{1/2} \geq 13.$ s	Selected value

Table CVIII Spontaneous fission half-life of ^{260}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ghiorso[197] (1970)	> 8.	$\lambda_f / \lambda_{tot} < 0.20$, $t_{1/2} = 1.6$ s.
Bemis[198] (1977)	15.8 ± 1.7	$\lambda_f / \lambda_{tot} = 0.096 \pm 0.006$
Recommended value	$t_{1/2} = 16. \pm 2.$ s	Selected value

Table CIX Spontaneous fission half-life of ^{261}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Flerov[170] (1970)	≈ 7.	$\lambda_f / \lambda_{tot} \approx 0.25$, $t_{1/2} = 1.8$ s
Ghiorso[199] (1971)	≥ 3.6	$\lambda_f / \lambda_{tot} \leq 0.50$
Lane[200] (1998)	> 10.	$\lambda_f / \lambda_{tot} < 0.18$
Recommended value	$t_{1/2} > 10.$ s	Selected value

Table CX Spontaneous fission half-life of ^{262}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Ghiorso[199] (1971)	> 67.	$\lambda_f / \lambda_{tot} < 0.60$
Bemis[201] (1977)	44. ± 7.	$\lambda_f / \lambda_{tot} = 0.78 \pm 0.06$
Druin[202] (1979)	≈ 59.	$\lambda_f / \lambda_{tot} \approx 0.60$
Gregorich[203] (1988)	69.	$\lambda_f / \lambda_{tot} = 0.49 \pm 0.13$
Kratz[204] (1989)	67.	$\lambda_f / \lambda_{tot} = 0.51 \pm 0.11$
Kratz[205] (1992)	≥ 102.	$\lambda_f / \lambda_{tot} \leq 0.33$, may be all or partially due to SF of ^{262}Rf produced via electron capture
Recommended value	$t_{1/2} \geq 1.7$ min	Selected value

Table CXI Spontaneous fission half-life of ^{263}Db.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Hulet[206] (1988)	≈ 50.	$\lambda_f / \lambda_{tot} \approx 0.55$
Kratz[205] (1992)	47. ± 12.	$\lambda_f / \lambda_{tot} = 0.57 \pm 0.14$; $t_{1/2} = 27.$ s
Recommended value	$t_{1/2} = 0.8 \pm 0.2$ min	Selected value

Table CXII Spontaneous fission half-life of ^{258}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Hessberger[176] (1997)	2.9 (+ 1.3 / – 0.7)	$\lambda_f / \lambda_{tot} = 1.0$
Recommended value	$t_{1/2} \approx 2.9$ ms	Selected value

Table CXIII Spontaneous fission half-life of ^{259}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Demin[207] (1984)	> 0.1	Excitation function systematics
Oganessian[179] (1984)	> 0.96	$\lambda_f / \lambda_{tot} < 0.50$, $t_{1/2} = 0.48$ s
Münzenberg[208] (1985)	> 2.4	$\lambda_f / \lambda_{tot} < 0.20$, $t_{1/2} = 0.48$ s
Recommended value	$t_{1/2} > 2.4$ s	Selected value

Table CXIV Spontaneous fission half-life of ^{260}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Demin[207] (1984)	> 5.	$\lambda_f / \lambda_{tot} < 0.20$
Oganessian[179] (1984)	> 4.5	$\lambda_f / \lambda_{tot} < 0.80$, $t_{1/2} = 3.6$ ms
Münzenberg[208] (1985)	7.2 ± 4.4	$\lambda_f / \lambda_{tot} = 0.50$, $t_{1/2} = 3.6$ ms
Recommended value	$t_{1/2} = 7. \pm 4.$ ms	Selected value

Table CXV Spontaneous fission half-life of ^{261}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Demin[207] (1984)	> 0.4	Excitation function systematics
Münzenberg[208] (1985)	> 2.6	$\lambda_f / \lambda_{tot} < 0.10$, $t_{1/2} = 0.26$ s
Recommended value	$t_{1/2} > 2.6$ s	Selected value

Table CXVI Spontaneous fission half-life of ^{263}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Druin[202] (1979)	≈ 1.1	$\lambda_f / \lambda_{tot} \approx 0.70$, $t_{1/2} = 0.8$ s
Lazarev[209] (1995)	> 2.7	$\lambda_f / \lambda_{tot} < 0.30$, $t_{1/2} = 0.8$ s
Recommended value	$t_{1/2} > 2.7$ s	Selected value

Table CXVII Spontaneous fission half-life ^{265}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Lougheed[210] (1994)	≥ 4. – 60.	$\lambda_f / \lambda_{tot} \leq 0.50$
Türler[211] (1998)	≥ 13.	$\lambda_f / \lambda_{tot} \leq 0.35$; authors used lower error limit $t_{1/2}$ = 4.7 s
	≥ 21.	using reported $t_{1/2}$ = 7.4 (+ 3.3 / – 2.7) s
Recommended value	$t_{1/2}$ ≥ 13. s	Selected value

Table CXVIII Spontaneous fission half-life ^{266}Sg.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Lougheed[210] (1994)	≥ 20. – 60.	$\lambda_f / \lambda_{tot} \leq 0.50$
Schädel[212] (1997)	≈ 55.	$\lambda_f / \lambda_{tot} \approx 0.62$; $t_{1/2}$ = 34 s
Türler[211] (1998)	≥ 11.	$\lambda_f / \lambda_{tot} \leq 0.82$; authors used lower error limit $t_{1/2}$ = 9 s.
	≥ 26.	using reported $t_{1/2}$ = 21. (+ 20. / – 12.) s
Recommended value	$t_{1/2}$ ≥ 11. s	Selected value

Table CXIX Spontaneous fission half-life of ^{261}Bh.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Oganessian[167] (1976)	≈ 0.01	$\lambda_f / \lambda_{tot} \approx 0.20$, $t_{1/2} \approx$ 2 ms
Münzenberg[213] (1989)	> 0.12	$\lambda_f / \lambda_{tot} < 0.10$, $t_{1/2}$ = 12 ms
Recommended value	$t_{1/2}$ > 0.12 s	Selected value

Table CXX Spontaneous fission half-life of ^{262}Bh.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Münzenberg[213] (1989)	> 0.9	$t_{1/2}$ = 102 ms; $\lambda_f / \lambda_{tot} < 0.12$, Münzenberg[214]
Recommended value	$t_{1/2}$ > 0.9 s	Selected value

Table CXXI Spontaneous fission half-life of ^{262m}Bh.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Münzenberg[213] (1989)	> 0.07	$t_{1/2}$ = 8 ms; $\lambda_f / \lambda_{tot} < 0.12$, Münzenberg[214]
Recommended value	$t_{1/2}$ > 0.07 s	Selected value

Table CXXII Spontaneous fission half-life of ^{264}Hs.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Oganessian[215] (1984)	> 1.	Excitation function systematics
Ninov[216] (1996)	≈ 2.	$\lambda_f / \lambda_{tot} \approx 0.50$
Recommended value	$t_{1/2}$ ≈ 2. ms	Selected value

Table CXXIII Spontaneous fission half-life of ^{265}Hs.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Demin[217] (1984)	> 20.	$t_{1/2}$ = 1.8 ms, Münzenberg[218]
Münzenberg[218] (1984)	> 5.6	$t_{1/2}$ = 1.8 ms; $\lambda_f / \lambda_{tot} < 0.32$, Hofmann[219]
Hofmann[220] (1995)	> 4.8	$t_{1/2}$ = 1.55 ± 0.20 ms; $\lambda_f / \lambda_{tot} < 0.32$, Hofmann[219]
Recommended value	$t_{1/2}$ > 4.8 ms	Selected value

Table CXXIV Spontaneous fission half-life of ^{267}Hs.

Reference Author (Year)	As Reported $t_{1/2}$ / s	Comments
Lazarev[209] (1995)	> 0.1	$\lambda_f / \lambda_{tot} < 0.20$; $t_{1/2}$ = 19. ms
Recommended value	$t_{1/2}$ > 0.1 s	Selected value

Table CXXV Spontaneous fission half-life of ^{266}Mt.

Reference Author (Year)	As Reported $t_{1/2}$ / ms	Comments
Münzenberg[221] (1988)	> 11.	$t_{1/2}$ = 3.4 ms; $\lambda_f / \lambda_{tot} < 0.32$, Hofmann[219]
Hofmann[222] (1997)	> 5.3	$t_{1/2}$ = 1.7 ms; $\lambda_f / \lambda_{tot} < 0.32$, Hofmann[219]
Recommended value	$t_{1/2}$ > 5.3 ms	Selected value

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Table CXXVI Recommended spontaneous fission and total half-lives and uncertainties.

Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)	Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)	Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)
^{208}Pb	$\geq 2 \times 10^{19}$		^{230}Th	$> 2. \times 10^{18}$	$7.54(10)^{4}$	^{232}Th	$(1.2 \pm 0.4) \times 10^{21}$	$1.4(10)^{10}$
^{231}Pa	$> 2. \times 10^{17}$	$3.25(10)^{4}$	^{230}U	$> 4. \times 10^{10}$	20.8 d	^{232}U	$> 6.8 \times 10^{15}$	68.9
^{233}U	$> 2.7 \times 10^{17}$	$1.59(10)^{5}$	^{234}U	$(1.5 \pm 0.2) \times 10^{16}$	$2.45(10)^{5}$	^{235}U	$(1.0 \pm 0.3) \times 10^{19}$	$7.04(10)^{8}$
^{236}U	$(2.5 \pm 0.1) \times 10^{16}$	$2.34(10)^{7}$	^{238}U	$(8.2 \pm 0.1) \times 10^{15}$	$4.46(10)^{9}$	^{237}Np	$> 1. \times 10^{18}$	$2.14(10)^{6}$
^{236}Pu	$(1.5 \pm 0.3) \times 10^{9}$	2.87	^{238}Pu	$(4.75 \pm 0.09) \times 10^{10}$	87.74	^{239}Pu	$(8. \pm 2.) \times 10^{15}$	$2.411(10)^{4}$
^{240}Pu	$(1.14 \pm 0.01) \times 10^{11}$	6537.	^{241}Pu	$< 6. \times 10^{16}$	14.4	^{242}Pu	$(6.77 \pm 0.07) \times 10^{10}$	$3.75(10)^{5}$
^{244}Pu	$(6.6 \pm 0.2) \times 10^{10}$	$8.00(10)^{7}$	^{241}Am	$(1.2 \pm 0.3) \times 10^{14}$	432.7	^{242m}Am	$> 3. \times 10^{12}$	141.
^{243}Am	$(2.0 \pm 0.5) \times 10^{14}$	$7.37(10)^{3}$	^{240}Cm	$(1.9 \pm 0.4) \times 10^{6}$	27. d	^{242}Cm	$(7.0 \pm 0.2) \times 10^{6}$	162.8 d
^{243}Cm	$(5.5 \pm 0.9) \times 10^{11}$	29.1	^{244}Cm	$(1.32 \pm 0.02) \times 10^{7}$	18.1	^{245}Cm	$(1.4 \pm 0.2) \times 10^{12}$	$8.48(10)^{3}$
^{246}Cm	$(1.81 \pm 0.02) \times 10^{7}$	$4.76(10)^{3}$	^{248}Cm	$(4.15 \pm 0.03) \times 10^{6}$	$3.48(10)^{3}$	^{250}Cm	$(1.13 \pm 0.05) \times 10^{4}$	$\approx 9.7(10)^{3}$
^{249}Bk	$(1.8 \pm 0.1) \times 10^{9}$	320 d	^{237}Cf	$\approx$ 21 s	2.1 s	^{238}Cf	21 ± 2 ms	21 ms
^{240}Cf	$\approx$ 53 min	1.1 min	^{242}Cf	$\geq$ 17. d	3.5 min	^{246}Cf	$(1.8 \pm 0.6) \times 10^{3}$	1.49 d
^{248}Cf	$(3.2 \pm 0.3) \times 10^{4}$	334 d	^{249}Cf	$(8. \pm 1.) \times 10^{10}$	351.	^{250}Cf	$(1.7 \pm 0.1) \times 10^{4}$	13.1
^{252}Cf	86. ± 1.	2.65	^{254}Cf	60.9 ± 0.9 d	60.5 d	^{256}Cf	12. ± 1. min	12 min
^{253}Es	$(6.3 \pm 0.2) \times 10^{5}$	20.47 d	^{254}Es	$> 2.5 \times 10^{7}$	276. d	^{254m}Es	> 10.	1.64 d
^{255}Es	$(2.6 \pm 0.1) \times 10^{3}$	40. d	^{242}Fm	0.8 ± 0.2 ms	0.8 ms	^{243}Fm	$\geq$ 50. s	0.2 s
^{244}Fm	3.3 ± 0.5 ms	3.7 ms	^{245}Fm	> 1.1 h	4. s	^{246}Fm	15 ± 5 s	1.2 s
^{248}Fm	10 ± 5 h	36. s	^{250}Fm	0.8 ± 0.2	30 min	^{250m}Fm	$\geq$ 0.07	1.8 s
^{252}Fm	125 ± 8	1.058 d	^{254}Fm	228 ± 1 d	3.240 h	^{255}Fm	$(1.0 \pm 0.6) \times 10^{4}$	20.1 h
^{256}Fm	2.9 ± 0.1 h	2.63 h	^{257}Fm	131. ± 3.	100.5 d	^{258}Fm	0.37 ± 0.02 ms	0.37 ms
^{259}Fm	1.5 ± 0.2 s	1.5 s	^{260}Fm	$\approx$ 4 ms	$\approx$ 4. ms	^{245}Md	0.9 ± 0.3 ms	0.9 ms
^{247}Md	$\approx$ 0.2 s	1.1 s	^{248}Md	$\geq$ 3.9 h	7. s	^{255}Md	$\geq$ 12.5 d	27. min
^{256}Md	> 1.9 d	1.30 h	^{257}Md	$\geq$ 23. d	5.5 h	^{258}Md	$\geq 4.7 \times 10^{3}$	51.5 d
^{258m}Md	$\geq$ 190 min	57. min	^{259}Md	< 1.62 ± 0.06 h	1.6 h	^{260}Md	27.8-38.1 d	27.8 d
^{250}No	0.25 ± 0.05 ms	0.25 ms	^{251}No	$\geq$ 10. s	0.8 s	^{252}No	9. ± 1. s	2.3 s
^{254}No	8. ± 2. h	55. s	^{254m}No	$\geq$ 2.3 min	0.28 s	^{256}No	9. ± 1. min	2.9 s
^{257}No	> 28. min	25. s	^{258}No	1.2 ± 0.2 ms	$\approx$1.2 ms	^{259}No	> 10. h	58. min
^{260}No	106. ± 8. ms	106. ms	^{262}No	$\approx$ 5. ms	$\approx$ 8. ms	^{252}Lr	$\geq$ 100. s	1. s
^{253}Lr	$\geq$ 2.2 min	1.3 s	^{254}Lr	$\geq$ 3.6 h	13. s	^{255}Lr	$\geq$ 6. h	22. s
^{256}Lr	$\geq$ 1. d	28. s	^{257}Lr	$\geq$ 0.55 h	0.65 s	^{258}Lr	> 78. s	3.9 s
^{259}Lr	31. ± 4. s	6.1 s	^{261}Lr	39 ± 12 min	40. min	^{262}Lr	> 1.5 d	3.6 h
^{253}Rf	$\approx$ 48.µs	$\approx$ 48 s	^{254}Rf	23. ± 3. µs	23. µs	^{255}Rf	2.9 ± 0.4 s	1.7 s
^{256}Rf	6.2 ± 0.2 ms	6.2 ms	^{257}Rf	> 5.6 min	4.7 s	^{258}Rf	14. ± 2. ms	12. ms

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Table CXXVI *continued*

Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)	Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)	Nuclide	SF $t_{1/2}$(a)	Tot $t_{1/2}$(a)
^{259}Rf	0.7 ± 0.4 min	3.4 s	^{260}Rf	20. ± 1. ms	20. ms	^{261}Rf	≥ 11. min	1.1 min
^{262}Rf	2.1 ± 0.2 s	2.1 s	^{255}Db	≈8 s	≈1.5 s	^{256}Db	≥ 6.5 s	2.6 s
^{257}Db	8. ± 6. s	1.5 s	^{258}Db	≥ 13 s	4.2 s	^{260}Db	16. ± 2. s	1.5 s
^{261}Db	< 10. s	1.8 s	^{262}Db	≥ 1.7 min	34. s	^{263}Db	0.8 ± 0.2 min	0.45 min
^{258}Sg	≈ 2.9 ms	≈ 2.9 ms	^{259}Sg	> 2.4 s	0.5 s	^{260}Sg	7. ± 4. ms	4. ms
^{261}Sg	> 2.6 s	0.26 s	^{263}Sg	> 2.7 s	0.8 s	^{265}Sg	> 13. s	7.4 s
^{266}Sg	> 11. s	≈ 21. s	^{261}Bh	> 0.12 s	12. ms	^{262}Bh	> 0.9 s	102. ms
^{262m}Bh	> 0.07 s	8. ms	^{264}Hs	≈ 2. ms	≈ 1. ms	^{265}Hs	> 4.8 ms	1.6 ms
^{267}Hs	≥ 0.1 s	19. ms	^{266}Mt	> 5.3 ms	1.7 ms			

TABLE REFERENCES

1. V. P. Zakharova, V. S. Zenkevich, V. B. Funshtein. *Phys of Atomic Nuclei*, **58** (4), 709 (1995).
2. E. Segre. *Phys. Rev.* **86**, 21 (1952).
3. S. P. Tretyakova, A. Sandulescu, V. L. Micheev, D. Hasegan, I. A. Lebedev, Yu. S. Zamyatnin, Yu. S. Korotkin, B. F. Myasoedov. JINR Rapid Communications No.13-85 Joint Institute for Nuclear Research, Dubna, USSR (1985).
4. A. V. Podguskaya, V. I. Kalashnikova, G. A. Stoliarov, E. D. Vorob'ev, G. N. Flerov. *Sov. JETP* **28**, 392 (1955).
5. G. N. Flerov, D. S. Klochikov, V. S. Skobkin, V. V. Terent'ev. *Sov. Phys. Doklady* **3**, 79 (1958).
6. A. Spadavecchia, B. Hahn. Helv. *Phys. Acta* **40**, 1063 (1967).
7. V. Emma, S. LoNigro. *Nucl. Instrum. Methods* **128**, 355 (1975).
8. R. Bonetti, C. Chiesa, A. Guglielmetti, R. Matheoud, G. Poli, V. L. Mikheev, S. P. Tretyakova. *Phy. Rev./C*, **51**, 2530 (1995).
9. A. Sandulescu, Yu. S. Zamyatnin, I. A. Lebedev, B. F. Myasoedov, S. P. Tretyakova, D. Hasegan. JINR Rapid Communications No. 4-84, 5 Joint Institute for Nuclear Research, Dubna, USSR (1984).
10. A. H. Jaffey, A. Hirsch, unpublished data, 1951 cited in E. K. Hyde. *The Nuclear Properties of the Heavy Elements*, Vol. III, p.75, Prentice-Hall, Englewood Cliffs (1964).
11. R. Bonetti, E. Fioretto, C. Migliorino, A. Pasinetti, F. Barranco, E. Vigezzi, R. A. Broglia. *Phys. Lett. B* **241**, 179 (1990).
12. B. M. Aleksandrov, L. S. Krivokhatskii, L. Z. Malkin, K. A. Petrzhak. *Sov. Atom. Energy* **20**, 352 (1966).
13. H. R. von Gunten, A. Gruetter, H. W. Reist, M. Baggenstos. *Phys. Rev. C* **23**, 1110 (1981).
14. A. Ghiorso, G. H. Higgins, A. E. Larsh, G. T. Seaborg, S. G. Thompson. *Phys. Rev.* **87**, 163 (1952).
15. S. Wang, P. B. Price, S. W. Barwick, K. J. Moody, E. K. Hulet. *Phys. Rev. C* **36**, 2717 (1987).
16. A. Grütter, H. R. von Gunten, V. Herrnberger, B. Hahn, U. Mosel, H. W. Reist, G. Stetten, Proc. Conf. Phys. Chem. of Fission, Rochester, 1973, Vol. I, 305 (1974).
17. A. H. Jaffey, A. Hirsch, unpublished data, 1949 cited in E. K. Hyde. *The Nuclear Properties of the Heavy Elements*, Vol. III, p. 75, Prentice-Hall, Englewood Cliffs (1964).
18. H. Conde, M. Holmberg. *J. Nucl. Energy* **25**, 331 (1971).
19. S. N. Belenky, M. D. Skorokhvatov, A. V. Etenko. *Sov. Atom. Energy* **55**, 528 (1983).
20. W. J. Whitehouse, W. Galbraith. *Phil. Mag.* **41**, 429 (1950).
21. R. L. Fleischer, P. B. Price. *Phys. Rev. B* **133**, 2975 (1964).
22. J. H. Roberts, R. Gold, R. J. Armani. *Phys. Rev.* **174**, 1482 (1968).
23. H. R.von Gunten. *Actinides Rev.* **1**, 275 (1969).
24. D. Galliker, E. Hugentobler, B. Hahn. *Helv. Phys. Acta* **43**, 593 (1970).
25. D.Storzer, Thesis Universitat Heidelberg (1970).
26. J. D. Kleeman, J. F. Lovering. *Geochim. Cosmochim. Acta* **35**, 637 (1971).
27. W. M. Thury. *Acta Phys. Aus.* **33**, 375 (1971).
28. M. P. T. Leme, C. Renner, M. Cattani. *Nucl. Instrum. Methods* **91**, 577 (1971).
29. H. A. Khan, S. A. Durrani. *Rad. Effects* **17**, 133 (1973).
30. K. N. Ivanov, K. A. Petrzhak. *Sov. Atom. Energy* **36**, 514 (1975).
31. G. A. Wagner, B. S. Reimer, H. Faul, R. van der Linden, R. Gijbels. *Geochim. Cosmochim. Acta* **39**, 1279 (1975).
32. K. Thiel, W. Herr. *Earth Planet. Sci. Letters* **30**, 50 (1976).
33. M. Kase, J. Kikuchi, T. Doke. *Nucl. Instrum. Methods* **154**, 335 (1978).
34. A. G. Popeko, G. M. Ter-Akopian. *Nucl. Instrum. Methods* **178**, 163 (1980).
35. E. R. V. Spaggiari. *An. Acad. Brasil. Cienc.* **52**, 213 (1980).

36. Z. N. R. Baptista, M. S. M. Mantovani, F. B. Ribeiro. *An. Acad. Brasil. Cienc.* **53**, 437 (1981).
37. J. C. Hadler, C. M. G. Lattes, A. Marques, M. D. D. Marques, D. A. B. Serra, G. Bigazzi, *Nucl. Tracks* **5**, 46 (1981).
38. H. G .de Carvalho, J. B. Martins, E. L. Medeiros, O. A. P. Tavares. *Nucl. Instrum. Methods* **197**, 417 (1982).
39. R. Vartanian. *Helv. Phys. Acta* **57**, 416 (1984).
40. M. P. Ivanov, G. M. Ter-Akopian, B. V. Fefilov, A. S. Voronin. *Nucl. Instrum. Methods* **A234**, 152 (1985).
41. S. S. Liu, F. Zhang. *Science in China* **34**, (9), 1120 (1991).
42. V. A. Druin, V. P. Perelygin, G. I. Khlebnikov. *Sov. Phys. JETP* **13**, 913 (1961).
43. Ju. A. Selickij, V. B. Funstein, V. A. Jakovlev. Proc. 38th Annual Conf. Nuclear Spectros. and Structure in Atomic Nuclei, Baku, 12–14 Apr., p. 131, Acad. Sci. USSR (1988).
44. A. A. Ogloblin, N. I. Venikov, S. K. Lisin, S. V. Pirozhkoov, V. A. Pchelin, Yu. F. Rodionov, V. M. Semochkin, V. A. Shabrov, I. K. Shvetsov, V. M. Shubko, S. P. Tretyakova, V. L. Mikheev. *Phys. Lett. B* **235**, 35 (1990).
45. M. Hussonnois, J. F. Le Du, D.Trubert, R. Bonetti, A. Guglielmetti, T. Guzel, S. P. Tretyakova, V. L. Mikheev, A. N. Golovchenko, V. A. Ponomarenko, *JETP Lett.* **62**, 701 (1995).
46. A. H. Jaffey, A. Hirsch. Argonne Nat. Lab. Report ANL-4286 (1949).
47. J. D. Hastings, W. W. Strohm. *J. Inorg. Nucl. Chem.* 34, 25 (1972).
48. R. R. Gay, R. Sher. *Bull. Amer. Phys. Soc.* **20**, 160 (1975).
49. A. A. Druzhinin, V. N. Polynov, A. M. Korochkin, E. A. Nokitin, L. I. Lagutina. *Sov. J. At. Energy* **59**, 628 (1985).
50. E. M. Kindermann. Hanford Lab. Report HW-27660 (1953).
51. F. R. Barclay, W. Galbraith, K. M.Glover, G. R.Hall, W. J. Whitehouse. *Proc. Phys. Soc. (London)* **A67**, 646 (1954).
52. O. Chamberlain, G. W. Farwell, E. Segre. *Phys. Rev.* **94**, 156 (1954).
53. V. L. Mikheev, N. K. Skobelev, V. A. Druin, G. N. Flerov. *Sov. Phys. JETP* **10**, 612 (1959).
54. D. E. Watt, F. J. Bannister, J. B. Laidler, F. Brown. *Phys. Rev.* **126**, 264 (1962).
55. L. Z. Malkin, I. D. Alkhazov, A. S. Krivokhatsky, K. A. Petrzhak. *Atom. Energia* **15**, 158 (1963).
56. P. H. White, priv. comm. cited in *J. Nucl. Energy* **21**, 749 (1967).
57. P. Fieldhouse, D. S. Mather, E. R. Culliford. *J. Nucl. Energy* **21**, 749 (1967).
58. C. Budtz-Jorgensen, H. H. Knitter, M. Mailly, R. Vogt. Euratom Progr. Rep. NEANDC(E)-212–3, 5 (1980).
59. A. A. Androsenko, P. A. Androsenko, Yu. V. Ivanov, A. E. Konyaev, V. F. Kositsyn, E. M. Tsenter, V. T. Shchebolev. *Sov. J. At. Energy* **57**, 788 (1984).
60. N. Dytlewski, M. G. Hines, J. W. Boldeman. *Nucl. Sci. Eng.* **102**, 423 (1989).
61. Yu. V. Ivanov, A. E. Konyaev, V. F. Kositsyn, E. A. Khol'nova, V. T. Shchebolev, M. F. Yuden. *Sov. J. At. Energy* **70**, 491 (1991).
62. J. F. Mech, H. Diamond, M. H. Studier, P. R. Fields, A. Hirsch, C. M. Stevens, R. F. Barnes, D. J. Henderson, J. R. Huizenga. *Phys. Rev.* **103**, 340 (1956).
63. J. P. Butler, M. Lounsbury, J. S. Merritt. *Can. J. Chem.* **34**, 253 (1956).
64. J. W. Meadows, Argonne Nat. Lab. Report ANL/NDM-38 (1977).
65. N. A. Khan, H. A. Khan, K. Gul, M. Anwar, G. Hussain, R. A. Akber, A. Waheed, M. S. Shaikh. *Nucl. Instrum. Methods* **173**, 163 (1980).
66. P. R. Fields, J. E. Gindler, A. L. Harkness, M. H. Studier, J. R. Huizenga, A. M. Friedman, *Phys. Rev.* **100**, 172 (1955).
67. P. R. Fields, A. M. Friedman, J. Milsted, J. Lerner, C. N. Stevens, D. Metta, W. K. Sabine, *Nature* **212**, 131 (1966).
68. B. M. Gokhberg, S. M. Dubrovina, V. A. Shigih. *Sov. J. Nucl. Phys.* **25**, 11 (1977).

69. M. S. Moore, C. Budtz-Jorgensen, H. H. Knitter, C. E. Olsen, J. A. Wartena, H. Weigmann. Proc. Int. Conf. Nucl. Data for Sci. Technol., Sept. 6-10, 1982 at Antwerp, Belgium, p.74 (1983).
70. V. A. Druin, V. L. Mikheev, N. K. Skobelev. *Sov. Phys. JETP* **13**, 216 (1961).
71. R. Gold, R. J. Armani, J. H. Roberts. *Phys. Rev. C* **1**, 738 (1970).
72. M. Paul, I. Ahmad, W. Kutschera, *Phys. Rev. C* **34**, 1980 (1986).
73. K. J. Moody, E. K. Hulet, S. Wang, P. B. Price, S. W.Barwick. *Phys. Rev. C* **36**, 2710 (1987).
74. I. A. Kukushkin, V. E. Makarenko, Yu. D. Molchanov, G. A. Otroshchenko. *Phys. At. Nucl.* **56**, 1157 (1993).
75. J. T. Caldwell, S. C. Fultz, C. D. Bowman, R. W. Hoff. *Phys. Rev.* **155**, 1309 (1967)
76. A. G. Zelenkov, V. A. Pchelin, Yu. F. Rodionov, L. V. Chistyakov, V. S. Shiryeav, V. M. Shubko. *Sov. J. At. Energy* **60**, 492 (1986).
77. B. M. Aleksandrov, L. S. Krivokhatskii, L. Z. Malkin, K. A. Petrzhak. *Sov. J. At. Energy* **20**, 352 (1966).
78. B. A. Gvozdev, B. B. Zakhvataev, V. I. Kuznetsov, V. P. Perelygin, S. V. Pirozhkov, E. G. Chudinov, I. K. Shvetsov. *Sov. Radiochem.* **8**, 459 (1966).
79. G. C. Hanna, B. G. Harvey, N. Moss, P. R. Tunnicliffe. *Phys. Rev.* **81**, 466 (1951).
80. R. J. Armani, R. Gold. Proc. Symp. on Standardization of Radionuclides, IAEA-Vienna, Austria, p. 621 (1967).
81. H. Q. Zhang, J. C.Xu, T. Q.Wan. *Chin. J. Nucl. Phys.* **1**, 21 (1979).
82. K. Raghuraman, N. K. Chaudhuri, A. V. Jadhav, C. K. Sivaramakrishnan, R. H. Iyer. *Radiochem. Radioanal. Lett.* **55**, 1 (1982).
83. H. Umezawa, Fifth Research Coordination Meeting on Measurement and Evaluation of Transuranium Isotope Nuclear Data. Geel, Belgium. IAEA Rep. No. INDC(NDS)-138 p.32 (1982).
84. S.Usuda, H.Umezawa. *Nucl. Tracks Radiat. Meas.* **16**, 247 (1989).
85. V. N. Polynov, A. A. Druzhinin, A. M. Korochkin, E. A. Nikitin, V. A. Bochkarev, V. N. Vyachin, V. G. Lapin, M. Yu. Maksimov. *Atom. Energiya* **62**, 277 (1987).
86. L. Z. Malkin, I. D. Alkhazov, A. S. Krivokhatskii, K. A. Petrzhak, L. M. Belov. *Sov. J. At. Energy* **15**, 955 (1963).
87. 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).
88. D. M. Barton, P. G. Koontz. *J. Inorg. Nucl. Chem.* **32**, 769 (1970).
89. J. D. Hastings, W. W. Strohm. *J. Inorg. Nucl. Chem.* **34**, 3597 (1972).
90. A. K. Pandey, R. C. Sharma, P. C. Kalsi, R. H. Iyer. *Nucl. Instrum. Methods B* **82**, 151 (1993).
91. A. A. Druzhinin, V. N. Polynov, S. P. Vesnovskii, A. M. Korochkin, A. A. Lbov, E. A. Nikitin. *Dokl. Akad. Nauk. SSSR* **280**, 1351 (1985).
92. 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).
93. S. M. Fried, G. L. Pyle, C. M. Stevens, J. R. Huizenga. *J. Inorg. Nucl. Chem.* **2**, 415 (1956).
94. D. H. Metta, H. Diamond, F. R. Kelly. *J. Inorg. Nucl. Chem.* **31**, 1245 (1969).
95. K. W. MacMurdo, R. M. Harbour, R. W. Benjamin. *J. Inorg. Nucl. Chem.* **33**, 1241 (1971).
96. J. P. Butler, T. A. Eastwood, H. G. Jackson, R. P. Schuman. *Phys. Rev.* **103**, 965 (1956).
97. J. E. McCracken, J. R. Stokely, R. D. Baybarz, C. E. Bemis, Jr., R. Eby, *J. Inorg. Nucl. Chem.* **33**, 3251 (1971).
98. J. R. Huizenga, H. Diamond. *Phys. Rev.* **107**, 1087 (1957).
99. Combined Radiochemistry Group, *Phys. Rev.* **148**, 1192 (1966).
100. D. N. Metta, P. E. Moreland. *J. Inorg. Nucl. Chem.* **29**, 2822 (1967).
101. 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).

102. 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).
103. A. Ghiorso, quoted in E. K. Hyde, "Nuclear Properties of the Heavy Elements", Vol III, p.77, Prentice Hall (1964).
104. T. A. Eastwood, J. P. Butler, M. J. Cabell, H. G. Jackson, R. P. Schuman, F. M. Rourke, T. L. Collins. *Phys. Rev.* **107**, 1635 (1957).
105. J. Milsted, E. P. Horwitz, A. M. Friedman, D. N. Metta. *J. Inorg. Nucl. Chem.* **31**, 1561 (1969).
106. P. E. Vorotnikov, S. M. Dubrovina, G. A. Otroshchenko, L. V. Chistyakov, V. A. Shigin, V. M. Shubko. *Sov. J. Nucl. Phys.* **10**, 419 (1970).
107. Yu. A. Lazarev, I. V. Shirokovsky, V. K. Utyonkov, S. P. Tretyakova, V. B. Kutner. *Nucl. Phy./A*, **588**, 501 (1995).
108. E. K. Hulet, S. Thompson, A. Ghiorso. *Phys. Rev.* **89**, 878 (1953).
109. A. M. Friedman, J. Milsted. *Phys. Rev.* **131**, 772 (1963).
110. N. N. Skobelev, B. A. Gvozdev, V. A. Druin. *Sov. J. At. Energy* **24**, 69 (1968).
111. E. K. Hulet, S. Thompson, A. Ghiorso. *Phys. Rev.* **95**, 1703 (1954).
112. V. P. Perelygin, S. P. Tretyakova, G. I. Khlebnikov, OIYaI Preprint 1635 Dubna, USSR (1964) quoted by Skobelev[110].
113. E. K. Hulet, J. F. Wild. *Radiochim. Radioanal. Lett.* **13**, 217 (1973).
114. N. I. Tarantin, G. V. Buklanov, Kim Su Men, Yu. S. Korotkin. *Sov. J. At. Energy* **62**, 407 (1987).
115. A. Ghiorso, S. G. Thompson, G. R. Choppin, B. G. Harvey. *Phys. Rev.* **94**, 1081 (1954).
116. L. Phillips, R. C. Gatti, R. Brandt, S. G. Thompson. *J. Inorg. Nucl. Chem.* **25**, 1085 (1963).
117. K. D. Sevier. *Nucl. Instrum. Methods* **14**, 318 (1961).
118. 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).
119. B. G. Harvey, S. G. Thompson, G. R. Choppin, A. Ghiorso. *Phys. Rev.* **99**, 337 (1955).
120. W. C. Bentley, H. Diamond, P. R. Fields, A. M. Friedman, J. E. Gindler, D. C. Hess, J. R. Huizenga, M. G. Inghram, A. H. Jaffey, L. B. Magnusson, W. M. Manning, J. F. Mech, G. L. Pyle, R. Sjoblom, C. M. Stevens, M. H. Studier, 55 Geneva Conf. **7**, 261 (1956).
121. C. E. Bemis, Jr., J. Halperin. *Nucl. Phys./A* **121**, 433 (1968).
122. D. C. Hoffman, J. B. Wilhelmy, J. Weber, W. R. Daniels, E. K. Hulet, R. W. Lougheed, J. H. Landrum, J. F. Wild, R. J. Dupzyk. *Phys. Rev./C* **21**, 972 (1980).
123. P. R. Fields, M. H. Studier, J. F. Mech, H. Diamond, A. M. Friedman, L. B. Magnusson, J. R. Huizenga. *Phys. Rev.* **94**, 209 (1954).
124. M. Jones, R. P. Schuman, J. P. Butler, G. Cowper, T. A. Eastwood, H. G. Jackson. *Phys. Rev.* **102**, 203 (1956).
125. W. C. McHarris, UCRL-11784 (July, 1965); quoted by Fields[126].
126. P. R. Fields, H. Diamond, A. M. Friedman, J. Milsted, J. L. Lerner, R. F. Barnes, R. K. Sjoblom, D. N. Metta, E. P. Horwitz. *Nucl. Phys./A* **96**, 440 (1967).
127. G. M. Ter-Akopyan, A. S. Iljinov, Yu. Ts. Oganessian, O. A. Orlova, G. S. Popeko, S. P. Tretyakova, V. I. Chepigin, B. V. Shilov, G. N. Flerov. *Nucl. Phys./A* **255**, 509 (1975).
128. M. Nurmia, T. Sikkeland, R. Silva, .Ghiorso, *Phys. Lett./B* **26**, 78 (1967).
129. V. A. Druin, N. K. Skobelev, V. I. Rud', *Sov. J. Nucl. Phys.* **12**, 74 (1971).
130. V. Ninov, F. P. Hessberger, S. Hofmann, H. Folger, G.Münzenberg, P. Armbruster, A. V. Yeremin, A. G. Popeko, M. Leino, S. Saro, *Z. Phys./A* **356**, 11 (1996).
131. Yu. A. Lazarev, Yu. V. Lobanov, R. N. Sagaidak, V. K. Utyonkov, M. Hussonnois, Yu. P. Kharitonov, I. V. Shirokovsky, S. P. Tretyakova, Yu. Ts. Oganessian. *Phys. Scripta* **39**, 422 (1989).
132. A. M. Friedman, J. E. Gindler, R. F. Barnes, R. Sjoblom, P. R. Fields. *Phys. Rev.* **102**, 585 (1956).
133. Argonne Heavy Element Group, Oak Ridge Trans-uranium Symposium (Nov. 1966).
134. I. Ahmad, J. L. Lerner. *Nucl. Phys./A* **413**, 423 (1984).

135. G. R. Choppin, S. G. Thompson, A. Ghiorso, B. G. Harvey. *Phys. Rev.* **94**, 1080 (1954).
136. G. R. Choppin, B. G. Harvey, S. G. Thompson, A. Ghiorso. *Phys. Rev.* **98**, 1519 (1955).
137. L. Phillips, R. Gatti, A. Chesne, L. Muga, S. Thompson. *Phys. Rev. Lett.* 1, 215 (1958).
138. T. Sikkeland, A. Ghiorso, R. Latimer, A. E. Larsh. *Phys. Rev.* **140**, B277 (1965).
139. R. W. Hoff, J. E. Evans, E. K. Hulet, R. J. Dupzyk, B. J. Qualheim. *Nucl. Phys./A* **115**, 225 (1968).
140. E. K. Hulet, R. W. Hoff, J. E. Evans, R. W. Lougheed. *Phys. Rev. Lett.* **13**, 343 (1964).
141. J. F. Wild, E. K. Hulet, R. W. Lougheed. *J. Inorg. Nucl. Chem.* **35**, 1063 (1973).
142. E. K. Hulet, J. F. Wild, R. W. Lougheed, J. E. Evans, B. J. Qualheim, M. Nurmia, A. Ghiorso. *Phys. Rev. Lett.* **26**, 523 (1971).
143. E. K. Hulet, R. W. Lougheed, J. F. Wild, R. J. Dougan, K. J. Moody, R. L. Hahn, C. M. Henderson, R. J. Dupzyk, G. R. Bethune. *Phys. Rev./C* **34**, 1394 (1986).
144. E. K. Hulet, R. W. Lougheed, J. H. Landrum, J. F. Wild, D. C. Hoffman, J. Weber, J. B. Wilhelmy. *Phys. Rev./C* **21**, 966 (1980).
145. D. C. Hoffman, D. Lee, A. Ghiorso, M. J. Nurmia, K. Aleklett, M. Leino. *Phys. Rev./C* **24**, 495 (1981).
146. L. P. Somerville, M. J. Nurmia, J. M. Nitschke, A. Ghiorso, E. K. Hulet, R. W. Lougheed, *Phys. Rev./C* **31**, 1801 (1985).
147. R. W. Lougheed, E. K. Hulet, J. F. Wild, R. J. Dougan, R. J. Dupzyk, C. M. Henderson, K. J. Moody, R. E. Glaser R. L. Hahn, K. Sümmerer, G. R. Bethune. Livermore Nat. Lab Rept. UCRL-JC-109951 (1992).
148. S. Hofmann, V. Ninov, F. P. Hessberger, H. Folger, G. Münzenberg, H. J. Schött, P. Armbruster, A. N. Andreyev, A. G. Popeko, A. V. Yeremin, M. E. Leino, R. Janik, S. Saro, M. Veselsky, Darmstadt Annual Report 1993, GSI 94-1, 64 (March 1994).
149. Yu. P. Gangrsky, M. B. Miller, L. V. Mikhailov, I. F. Kharisov. *Sov. J. Nucl. Phys.* **31**, 162 (1980).
150. R. W. Hoff, E. K. Hulet, R. J. Dupzyk, R. W. Lougheed, J. E. Evans. *Nucl. Phys./A* **169**, 641 (1971).
151. K. J. Moody, R. W. Lougheed, J. F. Wild, R. J. Dougan, E. K. Hulet, R. W. Hoff, C. M. Henderson, R. J. Dupzyk, R. L. Hahn, K. Sümmerer, G. D. O'Kelly, G. R. Bethune. *Nucl. Phys./A* **563**, 21 (1993).
152. R. W. Lougheed, E. K. Hulet, R. J. Dougan, J. F. Wild, R. J. Dupzyk, C. M. Henderson, K. J. Moody, R. L. Hahn, K. Sümmerer, G. R. Bethune. *J. Less-Common Met.* **122**, 461 (1986).
153. J. F. Wild, E. K. Hulet, R. W. Lougheed, P. A. Baisden, J. H. Landrum, R. J. Dougan, M. G. Mustafa. *Phys. Rev./C* **26**, 1531 (1982).
154. E. K. Hulet, J. F. Wild, R. J. Dougan, R. W. Lougheed, J. H. Landrum, A. D. Dougan, M. Schädel, R. L. Hahn, P. A. Baisden, C. M. Henderson, R. J. Dupzyk, K. Sümmerer, G. R. Bethune. *Phys. Rev. Lett.* **56**, 313 (1986).
155. A. Ghiorso, T. Sikkeland, M. J. Nurmia. *Phys. Rev. Lett.* **18**, 410 (1967).
156. C. E. Bemis, Jr., R. L. Ferguson, F. Plasil, R. J. Silva, F. Pleasonton, R. L. Hahn. *Phys. Rev./C* **15**, 705 (1977).
157. A. N. Andreyev, D. D. Bogdanov, V. I. Chepigin, A. P. Kabachenko, O. N. Malyshev, R. N. Sagaidak, L. I. Salamatin, G. M. Ter-Akopian, A. V. Yeremin. *Z. Phys. A* **345**, 389 (1993)
158. J. F. Wild, E. K. Hulet, R. W. Lougheed, K. J. Moody, B. B. Bandong, R. J. Dougan, A. Veeck. *J. Alloys Compd*, **213/214**, 86 (1994)
159. G. N. Flerov, V. I. Kuznetsov, N. K. Skobelev. *Sov. J. At. Energy* **22**, 611 (1967).
160. A. Türler, H. W. Gäggler, D. T. Jost, P. Armbruster, W. Brüchle, H. Folger, F. P. Hessberger, S. Hofmann, G. Münzenberg, V. Ninov, M. Schädel, K. Sümmerer, J. V. Kratz, U. Scherer. *Z. Phys./A* **331**, 363 (1988).
161. G. N. Flerov, A. G. Demin, V. A. Druin, Yu. V. Lobanov, V. L. Mikheev, S. M. Polikanov, V. A. Shchegolev. *Sov. J. Nucl. Phys.* **7**, 168 (1968).

162. D. C. Hoffman, D. M. Lee, K. E. Gregorich, M. J. Nurmia, R. B. Chadwich, K. B. Chen, K. R. Czerwinski, C. M. Gannett, H. L. Hall, R. A. Henderson, B. Kadkhodayan, S. A. Kreek, J. D. Leyba. *Phys. Rev./C* **41**, 631 (1990).
163. Yu. A. Lazarev, Proc. XXIV International Workshop on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg, Kleinwalsertal, Austria, 15–20 January 1996, Dubna Report, JINR-E7-96-82, (March 1996).
164. M. Nurmia, K. Eskola, P. Eskola, A. Ghiorso, UCRL-18667 p.63 (1969).
165. E. K. Hulet, J. F. Wild, R. J. Dougan, R. W. Lougheed, J. H. Landrum, A. D. Dougan, P. A. Baisden, C. M. Henderson, R. J. Dupzyk, R. L. Hahn, M. Schädel, K. Sümmerer, G. R. Bethune. *Phys. Rev./C* **40**, 770 (1989).
166. R. W. Lougheed, E. K. Hulet, J. F. Wild, K. J. Moody, R. J. Dougan, C. M. Gannett, R. A. Henderson, D. C. Hoffman, D. M. Lee. "50 Years With Nuclear Fission" Conference, Vol. II, p.694, Washington, DC, April 25–28, 1989, publ. by Amer. Nucl. Soc. Inc., LaGrange, IL 60525 (1989); see also report UCAR 10062-88, 135 (1988).
167. Yu. Ts. Oganessian, A. G. Demin, N. A. Danilov, G. N. Flerov, M. P. Ivanov, A. S. Iljinov, N. N. Kolesnikov, B. N. Markov, V. M. Plotko, S. P. Tretyakova. *Nucl. Phys./A* **273**, 505 (1976).
168. F. P. Hessberger, G. Münzenberg, S. Hofmann, Y. K. Agawal, K. Poppensieker, W. Reisdorf, K.-H. Schmidt, J. R. H. Schneider, W. F. W. Schneider, H. J. Schött, P. Armbruster, B. Thuma, C.-C. Sahm, D. Vermeulen, *Z. Phys./A* **322**, 557 (1985); F. P. Hessberger, Priv. Comm. (1986).
169. K. Eskola, P. Eskola, M. Nurmia, A. Ghiorso. *Phys. Rev./C* **4**, 632 (1971).
170. G. N. Flerov, Yu. Ts. Oganessian, Yu. V. Lobanov, Yu. A. Lazarev, S. P. Tretyakova, I. V. Kolesov, V. M. Plotko. *Sov. J. At. Energy* **29**, 967 (1970).
171. G. N. Flerov, Yu. Ts. Oganessian, Yu. V. Lobanov, Yu. A. Lazarev, S. P.T retyakova, I. V. Kolesov, V. M. Plotko. *Nucl. Phys./A* **160**, 181 (1971).
172. K. E. Gregorich, H. L. Hall, R. A. Henderson, J. D. Leyba, K. R. Czerwinski, S. A. Kreek, B. A. Kadkhodayan, M. J. Nurmia, D. M. Lee, D. C. Hoffman. *Phys. Rev./C* **45**, 1058 (1992).
173. T. M. Hamilton, K. E. Gregorich, D. M. Lee, K. R. Czerwinski, N. J. Hannink, C. D. Kacher, B. Kadkhodayan, S. A. Kreek, M. J. Nurmia, M. R. Lane, M. P. Neu, A. Türler, D. C. Hoffman. *Phys. Rev./C* **46**, 1873 (1992).
174. R. W. Lougheed, K. J. Moody, R. J. Dougan, J. F. Wild, E. K. Hulet, R. J. Dupzyk, C. M. Henderson, C. M. Gannett, R. A. Henderson, D. C. Hoffman, D. M. Lee, K. Sümmerer, R. L. Hahn, Lawrence Livermore Nat. Lab. Rept. UCAR 10062-87, 4-2 (1987).
175. G. N. Flerov, CERN 76-13, p.542 (July 15, 1976).
176. F. P. Hessberger, S. Hofmann, V. Ninov, P. Armbruster, H. Folger, G. Münzenberg, H. J. Schött, A. G. Popeko, A. V. Yeremin, A. N. Andreyev, S. Saro. *Z. Phys./A* **359**, 415 (1997).
177. Yu. Ts. Oganessian, A. G.Demin, A. S. Iljinov, S. P. Tretyakova, A. A. Pleve, Yu. E. Penionzhkevich, M. P. Ivanov, Yu. P. Tretyakov. *Nucl. Phys./A* **239**, 157 (1975).
178. G. Münzenberg, S. Hofmann, W. Faust, K. Güttner, F. P. Hessberger, W. Reisdorf, C. C. Sahm, K. H. Schmidt, B. Thuma, D. Vermeulen, P. Armbruster, Proc. Actinides-1981 Conf., Pacific Grove, California, p.223,Pergamon, Oxford (1981).
179. Yu. Ts. Oganessian, A. G. Demin, M. Hussonnois, S. P. Tretyakova, Yu. P. Kharitonov, V. K. Shirokovsky, O. Constantinescu, H. Bruchertseifer, Yu. S. Korotkin. *Z. Phys./A* **319**, 215 (1984).
180. F. P. Hessberger, G. Münzenberg, S. Hofmann, W. Reisdorf, K.-H. Schmidt, H. J. Schött, P. Armbruster, R. Hingmann, B. Thuma, D. Vermuelen. *Z.Phys./A* **321**,317 (1985).
181. Yu. Ts. Oganessian, M. Hussonnois, A. G. Demin, Yu. P. Kharitonov, V. K. Shirokovsky, H. Bruchertseifer, O. Constantinescu, Yu. S. Korotkin, S. P. Tretyakova, V. K. Utyonkov, I. V. Shirokovsky, J. Estevez. *Radiochim. Acta* **37**, 113 (1984).
182. C. E. Bemis, Jr., priv. comm. Quoted by M. R. Schmorak, *Nucl. Data Sheets* **59**, 611 (1990).
183. A. Ghiorso, M. Nurmia, J. Harris, K. Eskola, P. Eskola. *Phys. Rev. Lett.* **22**, 1317 (1969).

184. V. A. Druin, Yu. V. Lobanov, D. M. Nadcarni, Yu. P. Kharitonov, Yu. S. Korotkin, S. P. Tretyakova, V. I. Krashonkin. *Sov. J. At. Energy* **35**, 946 (1973).
185. C. E. Bemis, Jr., P. F. Dittner, R. L. Ferguson, D. C. Hensley, F. Plasil, F. Pleasonton. *Phys. Rev./C* **23**, 555 (1981).
186. G. N. Flerov, Yu. Ts. Oganessian, Yu. V. Lobanov, V. I. Kuznetsov, V. A. Druin, V. P. Perelygin, K. A. Gavrilov, S. P. Tretyakova, V. M. Plotko. *Phys. Lett.* **13**, 73 (1964).
187. Yu. Ts. Oganessian, Yu. V. Lobanov, S. P. Tretyakova, Yu. A. Lazarev, I. V. Kolesov, K. A. Gavrilov, V. M. Plotko, Yu. V. Poluboyarinov. *Sov. J. At. Energy* **28**, 502 (1970).
188. V. A. Druin, Yu. S. Korotkin, Yu. V. Lobanov, Yu. V. Poluboyarinov, R. N. Sagaidak, G. M. Solov'eva, S. P. Tretyakova, Yu.P.Kharitonov. *Sov. J. Nucl. Phys.* **24**, 131 (1976).
189. V. A. Druin, B. Bochev, Yu. S. Korotkin, V. N. Kosyakov, Yu. V. Lobanov, E. A. Minin, Yu. V. Poluboyarinov, A. G. Rykov, R. N. Sagaidak, S. P. Tretyakova, Yu. P. Kharitonov. *Sov. J. At. Ener*gy **43**, 785 (1977).
190. J. M. Nitschke, M. Fowler, A. Ghiorso, R. E. Leber, M. E. Leino, M. J. Nurmia, L. P. Sommerville, K. E. Williams, E. K. Hulet, J. H. Landrum, R. W. Lougheed, J. F. Wild, C. E. Bemis, Jr., R. J. Silva, P. Eskola. *Nucl. Phys./A* **352**, 131 (1981).
191. A. Ghiorso, M. Nurmia, K. Eskola, P. Eskola. *Phys. Lett./B* **32**, 95 (1970).
192. B. Kadkhodayan, A. Türler, K. E. Gregorich, P. A. Baisden, K. R. Czerwinski, B. Eichler, H. W. Gäggeler, T. M. Hamilton, D. T. Jost, C. D. Kacher, A. Kovacs, S. A. Kreek, M. R. Lane, M. F. Mohar, M. P. Neu, N. J. Stoyer, E. R. Sylwester, D. M. Lee, M. J. Nurmia, G. T. Seaborg, D. C. Hoffman. *Radiochim. Acta* **72**, 169 (1996).
193. Yu. A. Lazarev, Yu. V. Lobanov, Yu. Ts. Oganessian, V. K. Utyonkov, F. Sh. Abdullin, G. V. Buklanov, B. N. Gikal, S. Iliev, A. N. Mezentsev, A. N. Polyakov, I. M. Sedykh, I. V. Shirokovsky, V. G. Subbotin, A. M. Sukhov, Yu. S. Tsyganov, V. E. Zhuchko, R. W. Lougheed, K. J. Moody, J. F. Wild, E. K. Hulet, J. H. McQuaid. *Phys. Rev. Lett.* **73**, 624 (1994).
194. M. R. Lane, K. E. Gregorich, D. M. Lee, M. F. Mohar, M. Hsu, C. D. Kacher, B. Kadkhodayan, M. P. Neu, N. J. Stoyer, E. R. Sylwester, J. C. Yang, D. C. Hoffman. *Phys. Rev./C* **53**, 2893 (1996).
195. G. N. Flerov. JINR-E7-10128 (1976).
196. Yu. Ts. Oganessian. JINR-D7-83-644 (1983).
197. A. Ghiorso, M. Nurmia, K. Eskola, J. Harris, P. Eskola. *Phys. Rev. Lett.* **24**, 1498 (1970).
198. C. E. Bemis, Jr., P. F. Dittner, R. J. Silva, R. L. Hahn, J. R. Tarrant, L. D. Hunt, D. C. Hensley. *Phys. Rev./C* **16**, 1146 (1977).
199. A. Ghiorso, M. Nurmia, K. Eskola, P. Eskola. *Phys. Rev./C* **4**, 1850 (1971).
200. M. R. Lane, K. E. Gregorich, D. M. Lee, B. Wierczinski, C. A. McGrath, M. B. Hendricks, D. A. Shaughnessy, D. A. Strellis, E. R. Sylwester, P. A. Wilk, D. C. Hoffman. *Phys. Rev./C* **58**, 3413 (1998).
201. C. E. Bemis, Jr., R. L. Ferguson, F. Plasil, R. J. Silva, G. D. O'Kelly, M. L. Kiefer, R. L. Hahn, D. C. Hensley, E. K. Hulet, R. W. Lougheed. *Phys. Rev. Lett.* **39**, 1246 (1977).
202. V. A. Druin, B. Bochev, Yu. V. Lobanov, R. N. Sagaidak, Yu. P. Kharitonov, S. P. Tretyakova, G. G. Gul'bekyan, G. V. Buklanov, E. A. Erin, V. N. Kosyakov, A. G. Rykov. *Sov. J. Nucl. Phys.* **29**, 591 (1979).
203. K. E. Gregorich, R. A. Henderson, D. M. Lee, M. J. Nurmia, R. M. Chasteler, H. L. Hall, D. A. Bennett, C. M. Gannett, R. B. Chadwick, J. D. Leyba, D. C. Hoffman. *Radiochim. Acta* **43**, 223 (1988).
204. J. V. Kratz, H. R. Zimmermann, U. W. Scherer. *Radiochim. Acta* **48**, 121 (1989).
205. J. V. Kratz, M. K. Gober, H. R. Zimmermann, M. Schädel, W. Brüchle, E. Schimpf, K. E. Gregorich, A. Türler, N. J. Hannink, K. R. Czerwinski, S. A. Kreek, B.A.Kadkhodayan, D. M. Lee, M. J. Nurmia, D. C. Hoffman, H. Gäggeler, D. Jost, J. Kovacs, U. W. Scherer, A. Weber. *Phys. Rev./C* **45**, 1064 (1992).

206. E. K. Hulet, R. J. Dougan, K. J. Moody, R. W. Lougheed, J. F. Wild, K. Sümmerer, G. R. Bethune, R. L. Hahn, J.v an Aarle, K. E. Gregorich, D. C. Hoffman, UCAR 10062-88, 138 (1988).
207. A. G. Demin, S. P. Tretyakova, V. K. Utyonkov, I. V. Shirokovsky. *Z. Phys./A* **315**, 197 (1984).
208. G. Münzenberg, S. Hofmann, H. Folger, F. P. Hessberger, J. Keller, K. Poppensieker, B. Quint, W. Reisdorf, K.-H. Schmidt, H. J. Schött, P. Armbruster. *Z. Phys./A* **322**, 227 (1985).
209. Yu. A. Lazarev, Yu. V. Lobanov, Yu. Ts. Oganessian, Yu. S. Tsyganov, V. K. Utyonkov, F. Sh. Abdullin, S. Iliev, A. N. Polyakov, J. Rigol, I. V. Shirokovsky, V. G. Subbotin, A. M. Sukhov, G. V. Buklanov, B. N. Gikal, V. B. Kutner, A. N. Mezentsev, I. M. Sedykh, D. V. Vakatov, R. W. Lougheed, J. F. Wild, K. J. Moody, E. K. Hulet. *Phys. Rev. Lett.* **75**, 1903 (1995).
210. R. W. Lougheed, K. J. Moody, J. F. Wild, E. K. Hulet, J. H. McQuaid, Yu. A. Lazarev, Yu. V. Lobanov, Yu. Ts. Oganessian, V. K. Utyonkov, F. Sh. Abdullin, G. V. Buklanov, B. N. Gikal, S. Iliev, A. N. Mezentsev, A. N. Polyakov, I. M. Sedykh, I. V. Shirokovsky, V. G. Subbotin, A. M.Sukhov, Yu. S. Tsyganov, V. E. Zhuchko. *J. Alloys Compd.* **213/214**, 61 (1994). (See also ref. 192)
211. A. Türler, R. Dressler, B. Eichler, H. W. Gäggeler, D. T. Jost, M. Schädel, W. Brüchle, K.E. Gregorich, N. Trautmann, S. Taut. *Phys. Rev. C* **57** 1648 (1998).
212. M. Schädel, W. Brüchle, B.S chausten, E. Schimpf, E. Jäger, G. Wirth, R. Günther, J. V. Kratz, W. Paulus, A. Seibert, P. Thörle, N. Trautmann, S. Zauner, D. Schumann, M. Andrassy, R. Misiak, K. E. Gregorich, D. C. Hoffman, D. M. Lee, E. R. Sylwester, Y. Nagame, Y. Oura. *Radiochim. Acta* **77** 1349 (1997).
213. G. Münzenberg, P. Armbruster, S. Hofmann, F. P. Hessberger, H. Folger, J. G. Keller, V.Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, K.-H. Schmidt, J. R. H. Schneider, H. J. Schött, K. Sümmerer, I. Zychor, M. E. Leino, D. Ackermann, U. Gollerthan, E. Hanelt, W. Morawek, D. Vermeulen, Y. Fujita, T. Schwab. *Z. Phys./A* **333**, 163 (1989).
214. G. Münzenberg, S. Hofmann, F. P. Hessberger, D. Ackermann, H. Folger, V. Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, K.-H. Schmidt, H.-J. Schött, K. Sümmerer, P. Armbruster, U. Gollerthan, E. Hanelt, W. Morawek, Y. Fujita, T. Schwab, M. E. Leino, GSI Scientific Report 1987, GSI-88-1, (March 1988).
215. Yu. Ts. Oganessian, A. G. Demin, M. Hussonnois, S. P. Tretyakova, Yu. P. Kharitonov, V. K. Utyonkov, I. V. Shirokovsky, O. Constantinescu, H. Bruchertseifer, Yu. S. Korotkin. *Z. Phys./A* **319**, 215 (1984).
216. V. Ninov, cited in F. P. Hessberger, S. Hoffmann, V. Ninov, P. Armbruster, H. Folger, A. Lavrentev, M. E. Leino, G. Münzenberg, A. G. Popeko, S. Saro, Ch. Stodel, A. N. Yeremin, "Tours Symposium Nucl. Phys. III", Tours, France, Sept. 2–5, 1997 (1997).
217. A. G. Demin, M. Hussonnois, Yu. P. Kharitonov, S. P. Tretyakova, V. K. Utyonkov, I. V. Shirokovsky, O. Constantinescu, Yu. S. Korotkin, H. Bruchertseifer, V. G. Subbotin, J. Estevez, A. V. Rykhlyuk, V. M. Plotko, Yu. Ts. Oganessian, Dubna Report, JINR-P7-84-233 (1984).
218. G. Münzenberg, P. Armbruster, H. Folger, F. P. Hessberger, S. Hofmann, J. Keller, K. Poppensieker, W. Reisdorf, K.-H. Schmidt, H.-J. Schött. *Z. Phys./A* **317**, 235 (1984).
219. S. Hofmann, "Int. Summer School on Heavy Ion Physics", Dubna, USSR, Oct 3–12, 1989, GSI Report, GSI-89-3 (Nov. 1989).
220. S. Hofmann, V. Ninov, F. P. Hessberger, P. Armbruster, H. Folger, G. Münzenberg, H. J. Schött, A. G. Popeko, A. V. Yeremin, A. N. Andreyev, S. Saro, R. Janik, M. Leino. *Z. Phys./A* **350** 277 (1995).
221. G. Münzenberg, S. Hofmann, F. P. Hessberger, H. Folger, V. Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, H. J. Schött, K. Sümmerer, P. Armbruster, M. E. Leino, D. Ackermann, U. Gollerthan, E. Hanelt, W. Morawek, Y. Fujita, T. Schwab, A. Türler. *Z. Phys./A* **330**, 435 (1988).
222. S. Hofmann, F. P. Hessberger, V. Ninov, P. Armbruster, G. Münzenberg, C. Stodel, A. G. Popeko, A. V. Yeremin, S. Saro, M. Leino. *Z. Phys./A* **358** 377 (1997).

NOTE ADDED IN PROOF

There have been a number of recent articles published on spontaneous fission half-lives, since this paper was prepared. The impact of these new articles on the recommended half-life values that are presented in this paper are noted below.

^{238}U - Guedes reported a half-life value of $(8.30 \pm 0.24) \times 10^{15}$ a. This value is in agreement with the value of $(8.2 \pm 0.1) \times 10^{15}$ a, that was recommended in this paper. There is no change needed.

^{238}Pu - Kalsi reported a half-life value of $(4.72 \pm 0.25) \times 10^{10}$ a. This value is in agreement with the value of $(4.75 \pm 0.09) \times 10^{10}$ a, that was recommended in this paper. There is no change needed.

^{240}Pu - Kalsi reported a half-life value of $(1.10 \pm 0.10) \times 10^{11}$ a. This value is in agreement with the value of $(1.14 \pm 0.01) \times 10^{11}$ a, that was recommended in this paper. There is no change needed.

^{232}U - Bonetti reported a half-life value of $(2.6 \pm 0.5) \times 10^{15}$ a. This paper recommended only an lower limit to the half-life of $> 6.8 \times 10^{15}$ a, which was based on an earlier Bonetti measurement. The recommended value should now be changed to $(2.6 \pm 0.5) \times 10^{15}$ a, on the basis of this latest Bonetti measurement.

^{226}Ra - Mikheev reported a lower limit for this half-life of $> 4. \times 10^{18}$ a. This measurement should now be recommended, since there has been no previous measurements reported for this half-life.

REFERENCES

S. Guedes, J. C. Hadler N, P. J. Iunes, S. R. Paulo, A. Zuniga. *J. Radioanal. Nucl. Chem.* **245**, 441 (2000).

P. C. Kalsi. *J. Radioanal. Nucl. Chem.* **242**, 169 (1999).

R. Bonetti, A. Guglielmetti, V. L. Mikheev, S. P. Tretyakova, A. Cesana, M. Terrani. *Phys. Rev./C* **62**, 047304 (2000).

V. L. Mikheev, S. P. Tretyakova, M. Hussonnois, C. Le Naour, A. N. Golovchenko, O. V. Timofeeva. *Phys. Atomic Nuclei,* **62**, 1158 (1999).