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Spontaneous Fission Half-lives for Ground State Nuclides[#]

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ABSTRACT

Measurements of the spontaneous fission half-lives of nuclides of elements $Z = 90$ to 108 have been compiled and evaluated. Recommended values are presented.

Introduction

Spontaneous fission (SF) is a phenomenon exhibited by heavy nuclei, which was discovered over fifty years ago^{*}. 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 hindrance factors associated with odd-neutron or odd-proton nuclei. Other important modes are alpha-particle decay, beta-decay and electron capture. For some nuclei, a decay mode called heavy fragment emission^{**} can also occur, but it will not be considered in this paper. Excited states of these nuclei may decay via spontaneous fission. These so-called fission isomers will not be discussed here. 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 easily confused in some cases with SF. This process has been discussed in detail in a recent review^{***} and will not be considered here.

Analysis

All of the various experiments have been reanalysed and recommended half-life values for spontaneous fission are presented for over 100 nuclei of elements which range from thorium ($Z = 90$) to element $Z = 108$. An attempt has been made to revise values based on the latest parameters. If the α particle decay to spontaneous fission decay ratio had been measured, the spontaneous fission half-life is revised based on the latest value of the total half-life of that nuclide; this may not agree with that value as measured by the author. In the cases where it is possible to

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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 else a weighted average was calculated for each of the different experimental techniques used and an unweighted average of these half-lives was recommended. All of the tables indicate the particular method chosen.

Discussion of Results

There is a special problem with the case of spontaneous fission in ^{238}U . The measurement 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 other techniques. There can be a number of reasons for the lower specific activity. These would 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 1960's, 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 has poor dosimetry. In addition, the use of monitors other than Au or Co, 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 spontaneous $^{238}\text{U}/^{235}\text{U}$ induced track density ratio will be measured, which needs to be compensated 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 materials, it is not used to determine the correct spontaneous fission half-life for ^{238}U in our table.

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VIII.

Tabulated Results

Table I. Spontaneous Fission Half-life of ^{230}Th

Reference Author (Year)	As Reported $T_{1/2} / 10^{18} \text{ a}$	Comments
Segre ¹ (1952)	> 0.15	Ionization Chamber; not used
Tretyakova ² (1985)	> 2.	
Recommended Value = > 2. $\times 10^{18} \text{ a}$;		Selected Value

Table II. Spontaneous Fission Half-life of ^{232}Th

Reference Author (Year)	As Reported $T_{1/2} / 10^{21} \text{ a}$	Comments
Segre ¹ (1952)	> 0.0014	Ionization Chamber
Podguskaya ³ (1955)	> 0.1	Ionization Chamber
Flerov ⁴ (1958)	> 1.	Fiss.Frag. Proportional Chamber
Spadavecchia ⁵ (1967)	> 1.0 $\pm$ 0.3	Rotating Bubble Chamber
Emma ⁶ (1975)	> 0.7	Mica-Thorium Sandwich
Recommended Value = > 1.0 $\pm$ 0.3 $\times 10^{21} \text{ a}$;		Selected Value

Table III. Spontaneous Fission Half-life of ^{231}Pa

Reference Author (Year)	As Reported $T_{1/2} / 10^{17} \text{ a}$	Comments
Segre ¹ (1952)	> 0.11	Ionization Chamber; not used
Sandulescu ⁷ (1984)	> 2.	Fiss.Frag. Track Detector
Recommended Value = > 2. $\times 10^{17} \text{ a}$;		Selected Value

Table IV. Spontaneous Fission Half-life of ^{230}U

Reference Author (Year)	As Reported $T_{1/2} / 10^{10} \text{ a}$	Comments
Spadavecchia ⁵ (1967)	> 4.	Rotating Bubble Chamber
Recommended Value = > 4. $\times 10^{10} \text{ a}$;		Selected Value

Table V. Spontaneous Fission Half-life of ^{232}U

Reference Author (Year)	As Reported $T_{1/2} / 10^{15} \text{ a}$	Comments
Jaffey ⁸ (1951)	0.08 $\pm$ 0.055	
Segre ¹ (1952)	> 0.008	Ionization Chamber; not used
Bonetti ⁹ (1990)	> 6.84	Solid State Track detection
Recommended Value > 6.8 $\times 10^{15} \text{ a}$;		Selected Value

Table VI.

Spontaneous Fission Half-life of ^{233}U

Reference Author (Year)	As Reported $T_{1/2} / 10^{17} \text{ a}$	Comments
Segre ¹ (1952)	> 2.7	Ionization Chamber
Aleksandrov ¹⁰ (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 ¹¹ (1981)	> 2.7	97.11% enriched; Rotating Bubble Chamber; Corrected for (α, n, f) reaction
<i>Recommended Value = > $2.7 \pm 10^{17} \text{ a}$;</i>		<i>Selected Value</i>

Table VII.

Spontaneous Fission Half-life of ^{234}U

Reference Author (Year)	As Revised $T_{1/2} / 10^{16} \text{ a}$	Comments
Segre ¹ (1952)	> 0.6	Ionization Chamber; not used
Ghiorso ¹² (1952)	1.6 ± 0.7	Revised value; ionization chamber; not used
von Gunten ¹¹ (1981)	1.42 ± 0.08	99.36% enriched; Rotating Bubble Chamber; Corrected for (α, n, f) reaction
Wang ¹³ (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
<i>Weighted Average = $1.5 \pm 0.2 \pm 10^{16} \text{ a}$;</i>		<i>Recommended Value</i>

Table VIII.

Spontaneous Fission Half-life of ^{235}U

Reference Author (Year)	As Reported $T_{1/2} / 10^{16} \text{ a}$	Comments
Segre ¹ (1952)	0.18	Ionization chamber; not used
Aleksandrov ¹⁰ (1966)	0.35 ± 0.09	Fission track detectors; not used
Gruetter ¹⁴ (1973)	> 1.8	Rotating bubble chamber; no corrections; not used
von Gunten ¹¹ (1981)	9.8 ± 2.8	99.76% enriched; Rotating bubble chamber Corrected for (α, n, f) reaction
<i>Recommended Value = $1.0 \pm 0.3 \pm 10^{16} \text{ a}$;</i>		<i>Selected Value</i>

Table IX.

Spontaneous Fission Half-life of ^{238}U

Reference Author (Year)	As Reported $T_{1/2} / 10^{16} \text{ a}$	Comments
Jaffey ¹⁵ (1949)	$2. \pm 1.6$	
Conde ¹⁶ (1971)	2.7 ± 0.3	$^{238}\text{U} / ^{236}\text{U} = 0.30 \pm 0.03$
von Gunten ¹¹ (1981)	2.43 ± 0.13	99.88% enriched; Rotating bubble chamber; Corrected for (α, n, f) reaction
Belenky ¹⁷ (1983)	2.7 ± 0.4	Multiple neutron coincidence
<i>Weighted Average = $2.5 \pm 0.1 \pm 10^{16} \text{ a}$;</i>		<i>Recommended Value</i>

Table X.

Spontaneous Fission Half-life of ^{238}U

Reference Author (Year)	As Reported/ $(10^{-17} \text{ a}^{-1})$ Specific Activity	Comments
Whitehouse ¹⁸ (1950)	8.38 ± 0.52	Ionization Chamber
Segre ¹ (1952)	8.60 ± 0.29	Ionization Chamber
Fleischer ¹⁹ (1964)	6.85 ± 0.20	Mica-uranium Sandwich; not used
Roberts ²⁰ (1968)	7.03 ± 0.11	Mica-uranium Sandwich; not used
Spadavecchia ⁵ (1967)	8.42 ± 0.10	Rotating Bubble Chamber
von Gunten ²¹ (1969)	8.66 ± 0.22	Fission Products from ^{238}U
Galliker ²² (1970)	8.46 ± 0.06	Rotating Bubble Chamber
Storzer ²³ (1970)	8.49 ± 0.76	Fission Tracks in Dated Uranium Glass
Kleeman ²⁴ (1971)	6.8 ± 0.6	Lexan-uranium Sandwich; not used
Thury ²⁵ (1971)	8.66 ± 0.43	Third Order Coincidence
Leme ²⁶ (1971)	7.30 ± 0.16	Mica-uranium Sandwich; not used
Khan ²⁷ (1973)	6.82 ± 0.55	Mica-uranium Sandwich; not used
Ivanov ²⁸ (1975)	7.12 ± 0.32	Mica-uranium Sandwich; not used
Emma ⁸ (1975)	7.2 ± 0.2	Mica-uranium Sandwich; not used
Wagner ²⁹ (1975)	8.7 ± 0.6	Fission Tracks in Dated Uranium Glass
Thiel ³⁰ (1976)	8.57 ± 0.42	Fission Tracks in Dated Uranium Glass
Kase ³¹ (1978)	8.22 ± 0.20	Ionization Chamber
Popeko ³² (1980)	7.9 ± 0.4	Multiple Neutron Coincidence
Spaggiari ³³ (1980)	9.26 ± 0.17	Mica-uranium Sandwich; not used
Baptista ³⁴ (1981)	6.6 ± 0.2	Mica-uranium Sandwich; not used
Hadler ³⁵ (1981)	8.6 ± 0.4	Mica-uranium Sandwich; not used
de Carvalho ³⁶ (1982)	11.8 ± 0.7	Fission Tracks in Ordinary Glass; not used
Belenky ¹⁷ (1983)	8.35 ± 0.40	Multiple Neutron Coincidence
Vartanian ³⁷ (1984)	8.23 ± 0.43	Fission Tracks (Plastic, Uranium Foils); not used
Ivanov ³⁸ (1985)	8.29 ± 0.27	Double Ionization Chamber
Liu ³⁹ (1991)	7.03 ± 0.21	Solid State Track Detectors; not used

Recommended Half-life Value = $8.2 \pm 0.1 \times 10^{15} \text{ a}$; Unweighted Average of Techniques

Table XI.

Spontaneous Fission Half-life of ^{237}Np

Reference Author (Year)	As Reported $T_{1/2}/10^{18} \text{ a}$	Comments
Druin ⁴⁰ (1961)	$> 1.$	Nuclear Photographic Emulsion

Weighted Average $> 1. \times 10^{18} \text{ a}$;

Selected Value

Table XII.

Spontaneous Fission Half-life of ^{238}Pu

Reference Author (Year)	As Revised $T_{1/2}/10^9 \text{ a}$	Comments
Ghiorso ¹² (1952)	3.4 $\pm$ 1.2	Revised value; Ionization chamber; not used
Selickij ⁴¹ (1988)	2.09 $\pm$ 0.08	Two sources; Fragment detection in 2π geometry
Recommended Value = $2.1 \pm 0.1 \times 10^9 \text{ a}$;		Selected Value

Table XIII.

Spontaneous Fission Half-life of ^{239}Pu

Reference Author (Year)	As Revised $T_{1/2}/10^{10} \text{ a}$	Comments
Segre ¹ (1952)	3.8	Revised Value; Ionization Chamber; not used
Jaffey ⁴² (1949)	4.7 $\pm$ 0.6	Revised Value;
Druin ⁴⁰ (1961)	5.1 $\pm$ 0.6	Revised Value; Nuclear Photographic Emulsions
Hastings ⁴³ (1972)	4.77 $\pm$ 0.14	α /fission Ratio; Silicon Surface Barrier Detectors
Gay ⁴⁴ (1975)	4.63 $\pm$ 0.12	Fission Fragment Coincidences in Mica
Selickij ⁴¹ (1988)	5.01 $\pm$ 0.21	4 sources; Fragment Detection in 2π Geometry
Weighted Average = $4.75 \pm 0.09 \times 10^{10} \text{ a}$;		Recommended Value

Table XIV.

Spontaneous Fission Half-life of ^{240}Pu

Reference Author (Year)	As Reported $T_{1/2}/10^{15} \text{ a}$	Comments
Segre ¹ (1952)	5.5	Ionization Chamber; not used
Druzhinin ⁴⁵ (1985)	7.8 $\pm$ 1.6	α /fission activity
Recommended Value = $8. \pm 2. \times 10^{15} \text{ a}$;		Selected Value

Table XV.

Spontaneous Fission Half-life of ^{240}Pu

Reference Author (Year)	As Revised $T_{1/2}/10^{11} \text{ a}$	Comments
Kindermann ⁴⁶ (1953)	1.314 $\pm$ 0.028	Low geometry α counting; not used
Barclay ⁴⁷ (1954)	1.225 $\pm$ 0.030	Low geometry α counting; not used
Chamberlain ⁴⁸ (1954)	1.20	Low geometry α counting; not used
Mikhchev ⁴⁹ (1959)	1.20	α counting; gas scintillator; not used
Watt ⁵⁰ (1962)	1.34 $\pm$ 0.015	Low geometry α counting; not used
Malkin ⁵¹ (1963)	1.45 $\pm$ 0.02	α counting; gas scintillator; not used
White ⁵² (1967)	1.27 $\pm$ 0.05	No details available; not used
Fieldhouse ⁵³ (1967)	1.176 $\pm$ 0.025	Revised; spont. fiss. neutron emission rates
Budtz-Jorgensen ⁵⁴ (1980)	1.15 $\pm$ 0.03	Fragment spectra; ionization chamber
Androsenko ⁵⁵ (1984)	1.15 $\pm$ 0.03	Spontaneous fission neutron emission rates
Selickij ⁴¹ (1988)	1.17 $\pm$ 0.03	2 Sources; Fragment detection in 2π geometry
Dytlewski ⁵⁶ (1989)	1.12 $\pm$ 0.02	Neut.Coincid. + Low α Geom. ctg.
Ivanov ⁵⁷ (1989)	1.15 $\pm$ 0.02	Sf/ α ratio in two ^{240}Pu standards
Weighted Average = $1.14 \pm 0.01 \times 10^{11} \text{ a}$;		Recommended Value

Table XX.

Spontaneous Fission Half-life of ^{242m}Am

Reference Author (Year)	As Revised $T_{1/2}/10^{12} \text{ a}$	Comments
Caldwell ⁷⁰ (1967)	1.0 ± 0.4	Revised; Neut./fiss. frag. coincidence; not used
Zelenkov ⁷¹ (1986)	> 3.0	α /fission; silicon surface barrier detectors
Recommended Value = $> 3. \times 10^{12} \text{ a}$;		Selected Value

Table XXI.

Spontaneous Fission Half-life of ^{243}Am

Reference Author (Year)	As Reported $T_{1/2}/10^{14} \text{ a}$	Comments
Aleksandrov ⁷² (1966)	$> 0.33 \pm 0.03$	Glass fission track detector
Grozdev ⁷³ (1966)	$2. \pm 0.5$	Glass fission track detector
Recommended Value = $2.0 \pm 0.5 \times 10^{14} \text{ a}$;		Selected Value

Table XXII.

Spontaneous Fission Half-life of ^{240}Cm

Reference Author (Year)	As Reported $T_{1/2}/10^6 \text{ a}$	Comments
Ghiorso ¹² (1952)	1.9 ± 0.4	Ionization Chamber
Recommended Value = $1.9 \pm 0.4 \times 10^6 \text{ a}$;		Selected Value

Table XXIII.

Spontaneous Fission Half-life of ^{248}Cm

Reference Author (Year)	As Revised $T_{1/2}/10^6 \text{ a}$	Comments
Hanna ⁷⁴ (1951)	7.2 ± 0.2	Fission fragment counting, ionization chamber
Armani ⁷⁵ (1967)	6.82 ± 0.18	Revised value; Li-I fission neutron counting
Zhang ⁷⁶ (1979)	7.46 ± 0.06	Mica fission track detector
Raghuraman ⁷⁷ (1982)	7.15 ± 0.15	Solid state track detector
Umezawa ⁷⁸ (1982)	6.89 ± 0.17	Mica fiss track det.; not used see Usuda
Zelenkov ⁷¹ (1986)	6.98 ± 0.33	Revised value; α /fission Silicon surface barrier detectors
Usuda ⁷⁹ (1989)	6.96 ± 0.18	Mica fission track detector
Recommended Value = $7.0 \pm 0.2 \times 10^6 \text{ a}$;		Selected Value; Uncertainty covers the range of recent measurements

Table XXIV.

Spontaneous Fission Half-life of ^{243}Cm

Reference Author (Year)	As Revised $T_{1/2}/10^{11} \text{ a}$	Comments
Polynov ⁸⁰ (1987)	5.5 ± 0.9	Mica fission track detector
Recommended Value = $5.5 \pm 0.9 \times 10^{11} \text{ a}$;		Selected Value

Table XVI.

Spontaneous Fission Half-life of ^{241}Pu

Reference Author (Year)	As Reported $T_{1/2}/10^{16} \text{ a}$	Comments
Druzhinin ⁴⁵ (1985)	< 8.	α/f activity measured
Recommended Value = $6. \pm 10^{16} \text{ a}$		Selected Value

Table XVII.

Spontaneous Fission Half-life of ^{242}Pu

Reference Author (Year)	As Revised $T_{1/2}/10^{10} \text{ a}$	Comments
Studier ⁵⁸ (1958)	6.7 ± 0.7	Quoted by Mech ⁵⁹
Butler ⁵⁹ (1958)	6.85 ± 0.10	α/f fission ratio
Mech ⁵⁸ (1958)	6.79 ± 0.19	Revised Value for ^{242}Pu $\alpha T_{1/2}$
Druin ⁴⁰ (1981)	6.6 ± 0.7	gas scintillator; relative to ^{238}Pu $\alpha T_{1/2}$
Malkin ⁵¹ (1983)	7.45 ± 0.17	gas scintillator; specific activity
Meadows ⁶⁰ (1977)	6.74 ± 0.05	α/f fission ratio
Khan ⁶¹ (1980)	7.43	Mica fission track detector; not used
Selickij ⁴¹ (1988)	6.86 ± 0.26	Fission fragment detection in 2π geometry
Weighted Average = $6.77 \pm 0.07 \times 10^{10} \text{ a}$;		Recommended Value

Table XVIII.

Spontaneous Fission Half-life of ^{244}Pu

Reference Author (Year)	As Revised $T_{1/2}/10^{10} \text{ a}$	Comments
Fields ⁶² (1955)	2.5 ± 0.8	Ionization chamber; not used
Fields ⁶³ (1966)	6.67 ± 0.32	Revised value
Gokhberg ⁶⁴ (1977)	6.8 ± 0.8	No details
Khan ⁶¹ (1980)	7.32	Fission track detector; not used
Moore ⁶⁵ (1982)	6.56 ± 0.30	Ionization chamber; α counting; α spectrometry
Weighted Average = $6.6 \pm 0.2 \times 10^{10} \text{ a}$;		Recommended Value

Table XIX.

Spontaneous Fission Half-life of ^{241}Am

Reference Author (Year)	As Reported $T_{1/2}/10^{14} \text{ a}$	Comments
Segre ¹ (1952)	> 0.14	Ionization chamber; not used
Mikheev ⁴⁹ (1980)	> 2.	Gas scintillator; not used
Druin ⁴⁰ (1981)	2.3 ± 0.8	Gas scintillator
Galliker ²² (1970)	0.90 ± 0.04	Rotating bubble chamber
Gold ⁶⁷ (1970)	1.147 ± 0.024	Mica fission track detector
Paul ⁶⁸ (1986)	1.8 ± 0.4	Mica fission track detector
Moody ⁶⁹ (1987)	0.64	Phosphate glass track detector
Recommended Value = $1.0 \pm 0.4 \times 10^{14} \text{ a}$;		Selected Value with uncertainty to overlap the range

Table XXV.

Spontaneous Fission Half-life of ^{244}Cm

Reference Author (Year)	As Revised $T_{1/2}/10^7 \text{ a}$	Comments
Ghiorso ¹² (1952)	1.39 ± 0.20	Revised value; ionization chamber
Malkin ⁸¹ (1963)	1.46 ± 0.05	Gas scintillator
Metta ⁸² (1965)	1.346 ± 0.006	α /spontaneous fission ratio
Armani ⁷⁵ (1967)	1.33 ± 0.03	Li-I fission neutron counter
Barton ⁸³ (1970)	1.250 ± 0.007	Low geometry fission fragment counting
Hastings ⁸⁴ (1972)	1.343 ± 0.006	α /fission ratio; silicon surface barrier detector
Pandey ⁸⁵ (1990)	1.263 ± 0.025	CR-39 fission track detector; $\alpha/f=6.98 \times 10^5$
Weighted Average = $1.32 \pm 0.02 \times 10^7 \text{ a}$;		Recommended Value

Table XXVI.

Spontaneous Fission Half-life of ^{245}Cm

Reference Author (Year)	As Reported $T_{1/2}/10^{12} \text{ a}$	Comments
Druzhinin ⁸⁶ (1985)	1.4 ± 0.2	α /fission ratio
Recommended Value = $1.4 \pm 0.2 \times 10^{12} \text{ a}$;		Selected Value

Table XXVII.

Spontaneous Fission Half-life of ^{246}Cm

Reference Author (Year)	As Reported $T_{1/2}/10^7 \text{ a}$	Comments
Fields ⁸⁷ (1956)	> 1.24	Estimated from α /fission ratio; Not used
Fried ⁸⁸ (1956)	2.0 ± 0.8	fission counting; estimated mass; Not used
Metta ⁸⁹ (1969)	1.80 ± 0.01	α /fission ratio; 2π chamber, semi-conductor
MacMurdo ⁹⁰ (1971)	1.85 ± 0.02	α /fission ratio
Weighted Average = $1.81 \pm 0.02 \times 10^7 \text{ a}$;		Recommended Value

Table XXVIII.

Spontaneous Fission Half-life of ^{248}Cm

Reference Author (Year)	As Reported $T_{1/2}/10^8 \text{ a}$	Comments
Butler ⁹¹ (1956)	4.6 ± 0.5	specific fission activity; not used
Metta ⁹⁰ (1969)	4.22 ± 0.12	α /fission ratio; 2π chamber, semi-conductor
MacMurdo ⁹⁰ (1971)	4.20 ± 0.05	Relative activity to ^{244}Cm
McCracken ⁹² (1971)	4.115 ± 0.034	Specific fission activity; Ionization chamber
Weighted Average = $4.15 \pm 0.03 \times 10^8 \text{ a}$;		Recommended Value

Table XXIX.

Spontaneous Fission Half-life of ^{250}Cm

Reference Author (Year)	As Reported $T_{1/2}/10^4 \text{ a}$	Comments
Huizenga ⁹³ (1957)	2.3	Estimated value; not used
CRG ⁹⁴ (1966)	1.74 ± 0.24	Preliminary PAR bomb shot results; not used
Metta ⁹⁵ (1967)	1.13 ± 0.05	Ionization chamber; PAR bomb shot results
<i>Recommended Value = $1.13 \pm 0.05 \times 10^4 \text{ a}$;</i>		<i>Selected Value</i>

Table XXX.

Spontaneous Fission Half-life of ^{240}Bk

Reference Author (Year)	As Reported $T_{1/2}/10^9 \text{ a}$	Comments
Magnusson ⁹⁶ (1954)	> 0.2	Ion Chamber; $\beta/f = 3.78 \times 10^8$
Diamond ⁹⁷ (1954)	> 0.01	Ionization chamber
Ghiorso ⁹⁸ (1956)	0.6	
Eastwood ⁹⁹ (1957)	> 1.4	Ionization chamber
Milsted ¹⁰⁰ (1969)	1.87 ± 0.09	Parallel Plate Ion Chamber
Vorotnikov ¹⁰¹ (1970)	1.65 ± 0.17	Fiss.Frag.Glass Detector
<i>Weighted Average = $1.8 \pm 0.1 \times 10^9 \text{ a}$;</i>		<i>Recommended Value</i>

Table XXXI.

Spontaneous Fission Half-life of ^{240}Cf

Reference Author (Year)	As Reported $T_{1/2}/10^3 \text{ a}$	Comments
Hulet ¹⁰² (1953)	2.1 ± 0.3	$\alpha/f = 5.2 \times 10^5$
Friedman ¹⁰³ (1963)	1.34 ± 0.16	Ion chamb.; $\alpha/f = 3.3 \times 10^5$
Skobelev ¹⁰⁴ (1968)	2.0 ± 0.2	Au-Si det.; $\alpha/f = 4.9 \times 10^5$
<i>Weighted Average = $1.8 \pm 0.6 \times 10^3 \text{ a}$;</i>		<i>Recommended Value</i>

Table XXXII.

Spontaneous Fission Half-life of ^{240}Cf

Reference Author (Year)	As Reported $T_{1/2}/10^4 \text{ a}$	Comments
Hulet ¹⁰⁵ (1954)	0.9	$\alpha/f \approx 10^4$
Perelygin ¹⁰⁶ (1964)	3.4 ± 1.5	Ion chamber; quoted by Skobelev ¹⁰⁴
Skobelev ¹⁰⁴ (1968)	4.1 ± 0.4	Mica det.; $\alpha/f = 4.3 \times 10^4$
Hulet ¹⁰⁷ (1973)	3.2 ± 0.3	$\alpha/f = 3.5 \times 10^4$
<i>Recommended Value = $3.2 \pm 0.3 \times 10^4 \text{ a}$;</i>		<i>Selected Value</i>

Table XXXIII.

Spontaneous Fission Half-life of ^{240}Cf

Reference Author (Year)	As Reported $T_{1/2}/10^{10} \text{ a}$	Comments
Magnusson ⁹⁶ (1954)	> 0.0005	
Diamond ⁹⁷ (1954)	> 0.0001	Ionization chamber
Ghiorso ⁹⁸ (1956)	> 0.15	
Eastwood ⁹⁹ (1957)	> 0.045	Ionization chamber; $\alpha/f < 1.3 \times 10^6$
Milsted ¹⁰⁰ (1969)	6.87 ± 0.33	Parallel Plate Ion Chamber; $\alpha/f = 1.2 \times 10^4$
Vorotnikov ¹⁰¹ (1969)	> 0.2	Ionization chamber
Tarantin ¹⁰⁸ (1987)	8.5 ± 0.5	
Recommended Value = $8. \pm 1. \times 10^{10} \text{ a}$;		Selected Value

Table XXXIV.

Spontaneous Fission Half-life of ^{250}Cf

Reference Author (Year)	As Reported $T_{1/2}/10^4 \text{ a}$	Comments
Ghiorso ¹⁰⁹ (1954)	0.5	$\alpha/f = 400$; not used
Diamond ⁹⁷ (1954)	> 1.4	Revised
Magnusson ⁹⁶ (1954)	1.9 ± 0.6	Parallel Plate Ion Chamber; $\alpha/f = 1460 \pm 350$
Phillips ¹¹⁰ (1963)	1.73 ± 0.06	prop.ctr. $\alpha/f = 1330 \pm 45$
Metta ⁸² (1965)	1.66 ± 0.08	$\alpha/f = 1260 \pm 40$
Recommended Value = $1.7 \pm 0.1 \times 10^4 \text{ a}$;		Selected Value

Table XXXV.

Spontaneous Fission Half-life of ^{252}Cf

Reference Author (Year)	As Reported $T_{1/2}/\text{a}$	Comments
Ghiorso ¹⁰⁹ (1954)	100.	$\alpha/f = 42$.; not used
Diamond ⁹⁷ (1954)	$75. \pm 15.$	Revised
Magnusson ⁹⁶ (1954)	$79. \pm 10.$	Parallel Plate Ion Chamber; $\alpha/f = 30 \pm 1$
Harvey ¹¹¹ (1955)	$85. \pm 15.$	
Eastwood ⁹⁹ (1957)	$82. \pm 6.$	Ionization chamber; $\alpha/f = 32. \pm 2.$
Sevier ¹¹² (1961)	98.9	Revised ; $\alpha/f = 36.45$
Metta ⁸² (1965)	85.5 ± 0.5	$\alpha/f = 31.3 \pm 0.2$
Aleksandrov ¹¹³ (1970)	85.2 ± 0.4	Si det.; $\alpha/f = 31.5, 31.1$
Pandey ⁸⁵ (1990)	83.7 ± 0.9	CR-39 fission track detector; $\alpha/f = 31.56$
Recommended Value = $85. \pm 1. \text{ a}$;		Selected Value

Table XXXVI.**Spontaneous Fission Half-life of ^{254}Cf**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}/d$</u>	<u>Comments</u>
Fields ⁸⁷ (1956)	55.	
Bentley ¹¹⁴ (1956)	60. $\pm$ 10.	
Huizenga ⁹³ (1957)	60.5 $\pm$ 1.1	Ion chamber; rev Metta ⁸² ; Pct SF Bemis ¹¹⁵
Phillips ¹¹⁰ (1963)	60.7 $\pm$ 0.2	Corr. for ^{250}Cf ; rev. Pct SF Bemis ¹¹⁵
Metta ⁸² (1965)	62.1 $\pm$ 1.1	Ion Chamber; rev. Pct SF Bemis ¹¹⁵
<i>Weighted Average = 60.9 $\pm$ 0.9 d;</i>		<i>Recommended Value</i>

Table XXXVII.**Spontaneous Fission Half-life of ^{256}Cf**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}/m$</u>	<u>Comments</u>
Hoffman ¹¹⁶ (1980)	12.3 $\pm$ 1.2	Ion Chamber
<i>Recommended Value = 12. $\pm$ 1. m;</i>		<i>Selected Value</i>

Table XXXVIII.**Spontaneous Fission Half-life of ^{253}Es**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}/10^5 y$</u>	<u>Comments</u>
Fields ¹¹⁷ (1954)	> 1.	No details
Jones ¹¹⁸ (1956)	7. $\pm$ 3.	Ion Chamber
Metta ⁸² (1965)	6.3 $\pm$ 0.2	$\alpha/f = 1.15 \pm 0.03 \times 10^7$
<i>Recommended Value = 6.3 $\pm$ 0.2 $10^5 y$;</i>		<i>Selected Value</i>

Table XXXIX.**Spontaneous Fission Half-life of ^{254}Es**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}/10^7 y$</u>	<u>Comments</u>
Ghiorso ⁹⁸ (1955)	0.015	quoted by Hyde
McHarris ¹¹⁹ (1965)	0.068	Ionization chamber;
Fields ¹²⁰ (1967)	> 2.5	Ion Chamber; $f/\alpha < 3 \times 10^{-8}$
<i>Recommended Value > 2.5 $\times 10^7 y$;</i>		<i>Selected Value</i>

Table XL.**Spontaneous Fission Half-life of ^{254m}Es**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}/y$</u>	<u>Comments</u>
Fields ¹¹⁷ (1954)	> 10.	Pct sf < 0.045
<i>Recommended Value > 10. y;</i>		<i>Selected Value</i>

Table XLI.

Spontaneous Fission Half-life of ^{255}Es

Reference Author (Year)	As Reported $T_{1/2}/10^3 \text{ y}$	Comments
Fields ¹²⁰ (1967)	2.63 ± 0.14	Ion Chamber; $\beta/f = 2.22 \pm 0.10 \times 10^4$
Recommended Value = $2.6 \pm 0.1 \times 10^3 \text{ y}$;		Selected Value

Table XLII.

Spontaneous Fission Half-life of ^{257}Es

Reference Author (Year)	As Reported $T_{1/2}/\text{d}$	Comments
Popov ¹²¹ (1981)	8.7 ± 0.9	Measured neutron activity
Recommended Value = $8.7 \pm 0.9 \text{ d}$;		Selected Value

Table XLIII.

Spontaneous Fission Half-life of ^{242}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{ms}$	Comments
Ter-Akopyan ¹²² (1975)	0.8 ± 0.2	Pct Sf > 96.
Recommended Value = $0.8 \pm 0.2 \text{ ms}$;		Selected Value

Table XLIV.

Spontaneous Fission Half-life of ^{243}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{s}$	Comments
Ter-Akopyan ¹²² (1975)	> 50.	
Recommended Value > 50. s;		Selected Value

Table XLV.

Spontaneous Fission Half-life of ^{244}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{ms}$	Comments
Nurmia ¹²³ (1967)	3.3 ± 0.5	Spontaneous Fission Assumed
Ter-Akopyan ¹²² (1975)	4.	Pct Sf > 97.
Recommended Value = $3.3 \pm 0.5 \text{ ms}$;		Selected Value

Table XLVI.

Spontaneous Fission Half-life of ^{245}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{h}$	Comments
Ter-Akopyan ¹²² (1975)	> 1.1	
Recommended Value > 1.1 h;		Selected Value

Table XLVII.

Spontaneous Fission Half-life of ^{248}Fm

Reference Author (Year)	As Reported $T_{1/2}/s$	Comments
Nurmia ¹²³ (1967)	$15. \pm 5.$	Mica Det.;
Druin ¹²⁴ (1971)	$\approx 20.$	Solid State Det.;
Recommended Value = $15. \pm 5. s$;		Selected Value

Table XLVIII.

Spontaneous Fission Half-life of ^{249}Fm

Reference Author (Year)	As Reported $T_{1/2}/hr$	Comments
Nurmia ¹²³ (1967)	$10. \pm 5.$	Mica Det.; SF = 0.10 ± 0.05 pct.
Druin ¹²⁴ (1971)	$\approx 53.$	Solid State Det.; $\alpha/f \approx 6000$
Recommended Value = $10. \pm 5. hr$;		Selected Value

Table XLIX.

Spontaneous Fission Half-life of ^{250}Fm

Reference Author (Year)	As Reported $T_{1/2}/y$	Comments
Druin ¹²⁴ (1971)	≈ 9.5	Solid State Det.; $f/\alpha = 6 \times 10^{-6}$
Lazarev ¹²⁵ (1989)	0.83 ± 0.15	Pct Sf = $6.9 \pm 1.0 \times 10^{-5}$
Recommended Value = $0.8 \pm 0.2 y$;		Selected Value

Table L.

Spontaneous Fission Half-life of ^{252}Fm

Reference Author (Year)	As Reported $T_{1/2}/y$	Comments
Friedman ¹²⁶ (1956)	> 8.2	No details; Not used
AHEG ¹²⁷ (1966)	$115. \pm 60.$	
Ahmad ¹²⁸ (1967)	$125. \pm 8.$	$f/\alpha = (2.3 \pm 0.2) \times 10^{-5}$
Recommended Value = $125. \pm 8. y$;		Selected Value

Table LI.

Spontaneous Fission Half-life of ^{254}Fm

Reference Author (Year)	As Reported $T_{1/2}/d$	Comments
Fields ¹¹⁷ (1954)	$220. \pm 40.$	Ionization chamber
Choppin ¹²⁹ (1954)	$\approx 135.$	$\alpha/f \approx 10^3$
Choppin ¹³⁰ (1955)	209.	$\alpha/f = 1550$
Jones ¹¹⁸ (1956)	246.	Ion Chamber
Fields ¹²⁰ (1967)	$228. \pm 1.$	4π ctr. $\alpha/f = 1695 \pm 8$
Recommended Value = $228. \pm 1 d$;		Si barrier det. $\alpha/f = 1664 \pm 17$
		Selected Value

Table LII.

Spontaneous Fission Half-life of ^{255}Fm

Reference Author (Year)	As Reported $T_{1/2}/10^4 \text{ y}$	Comments
Phillips ¹¹⁰ (1963)	1.0 ± 0.6	Windowless Prop.Ctr.; Pct sf = 2.4×10^{-5}
<i>Recommended Value = $1.0 \pm 0.6 \times 10^4 \text{ y}$;</i>		<i>Selected Value</i>

Table LIII.

Spontaneous Fission Half-life of ^{256}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{min}$	Comments
Choppin ¹³⁰ (1955)	180. to 240.	
Phillips ¹³¹ (1958)	$160. \pm 10.$	Windowless Prop.Ctr.
Sikkeland ¹³² (1965)	$167. \pm 6.$	$\alpha/(\alpha+f) = 0.028 \pm 0.01$
Hoff ¹³³ (1968)	$171. \pm 2.$	Ion Chamber; $\alpha/(\alpha+f) = 0.081 \pm 0.003$
<i>Recommended Value = $2.9 \pm 0.1 \text{ h}$;</i>		<i>Selected Value</i>

Table LIV.

Spontaneous Fission Half-life of ^{257}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{y}$	Comments
Hulet ¹³⁴ (1964)	$100. \pm 20.$	$\alpha/f = 468. \pm 100.$
Sikkeland ¹³² (1965)	$\approx 131.$	$\alpha/f = 600.$
CRG ⁹⁴ (1966)	$129. \pm 45.$	$\alpha/f = 500. \pm 175.$
Wild ¹³⁵ (1973)	$131. \pm 3.$	$\alpha/f = 475. \pm 10.$
<i>Weighted Average = $131. \pm 3. \text{ y}$;</i>		<i>Recommended Value</i>

Table LV.

Spontaneous Fission Half-life of ^{258}Fm

Reference Author (Year)	As Reported $T_{1/2}/\mu\text{s}$	Comments
Hulet ¹³⁶ (1971)	$380. \pm 60.$	Fission tracks in mica; 3σ
Hulet ¹³⁷ (1986)	$360. \pm 20.$	Time correlation meas.; 1σ
<i>Weighted Average = $0.37 \pm 0.02 \text{ ms}$;</i>		<i>Recommended Value</i>

Table LVI.

Spontaneous Fission Half-life of ^{259}Fm

Reference Author (Year)	As Reported $T_{1/2}/\text{s}$	Comments
Hulet ¹³⁸ (1980)	1.5 ± 0.3	Pct SF = 100
Hoffman ¹³⁹ (1981)	1.5 ± 0.2	Pct SF = 100
Somerville ¹⁴⁰ (1985)	1.6 ± 0.1	Pct SF = 100
<i>Recommended Value = $1.5 \pm 0.2 \text{ s}$;</i>		<i>Selected Value</i>

Table LVII.

Spontaneous Fission Half-life of ^{260}Fm

Reference Author (Year)	As Reported $T_{1/2} / \text{ms}$	Comments
Lougheed ¹⁴¹ (1992)	$\approx 4.$	Pct SF = 100
Recommended Value $\approx 4. \text{ ms}$;		Selected Value

Table LVIII.

Spontaneous Fission Half-life of ^{255}Md

Reference Author (Year)	As Reported $T_{1/2} / \text{d}$	Comments
Hoff ¹⁴² (1971)	> 12.5	Pct Sf < 0.15
Recommended Value $> 12.5 \text{ d}$;		Selected Value

Table LIX.

Spontaneous Fission Half-life of ^{256}Md

Reference Author (Year)	As Reported $T_{1/2} / \text{d}$	Comments
Hoff ¹⁴² (1971)	> 1.9	Pct Sf < 2.8
Recommended Value $> 1.9 \text{ d}$;		Selected Value

Table LX.

Spontaneous Fission Half-life of ^{257}Md

Reference Author (Year)	As Reported $T_{1/2} / \text{d}$	Comments
Sikkeland ¹³² (1965)	> 2.9	Pct. SF < 7.7
Hoff ¹⁴² (1971)	> 6.1	Pct. SF < 3.6
Moody ¹⁴³ (1992)	$> 23.$	Pct. SF < 1.0
Recommended Value $> 23. \text{ d}$;		Selected Value

Table LXI.

Spontaneous Fission Half-life of ^{258}Md

Reference Author (Year)	As Reported $T_{1/2} / 10^3 \text{ y}$	Comments
Lougheed ¹⁴⁴ (1986)	$> 150.$	
Moody ¹⁴³ (1992)	> 4.7	Pct. SF < 0.003
Recommended Value $> 4.7 \times 10^3 \text{ y}$;		Selected Value

Table LXII.

Spontaneous Fission Half-life of ^{259}Md

Reference Author (Year)	As Reported $T_{1/2} / \text{m}$	Comments
Wild ¹⁴⁵ (1982)	$106. \pm 12.$	Pct. SF > 97.
Moody ¹⁴³ (1992)	96.0 ± 3.6	Pct. SF $\approx 100.$
Recommended Value $= 1.60 \pm 0.06 \text{ h}$;		Selected Value

Table LXIII.

Spontaneous Fission Half-life of ^{260}Md

Reference Author (Year)	As Reported $T_{1/2}$ / d	Comments
Hulet ¹⁴⁰ (1986)	45.4 ± 0.7	Pct Sf ≈ 70 .
Lougheed ¹⁴¹ (1992)	< 38 .	Pct Sf > 73 .
Recommended Value < 38 . d;		Selected Value

Table LXIV.

Spontaneous Fission Half-life of ^{250}No

Reference Author (Year)	As Reported $T_{1/2}$ / ms	Comments
Ter-Akopyan ¹²² (1975)	0.25 ± 0.05	Pct Sf ≈ 100 .
Recommended Value $= 0.25 \pm 0.05$ ms;		Selected Value

Table LXV.

Spontaneous Fission Half-life of ^{251}No

Reference Author (Year)	As Reported $T_{1/2}$ / s	Comments
Ter-Akopyan ¹²² (1975)	> 10 .	Pct Sf ≈ 100 .
Recommended Value > 10 . s;		Selected Value

Table LXVI.

Spontaneous Fission Half-life of ^{252}No

Reference Author (Year)	As Reported $T_{1/2}$ / s	Comments
Ghiorso ¹⁴⁷ (1987)	4.6 ± 0.6	Pct Sf = 50.; total $T_{1/2}$ Lazarev ¹²³
Bemis ¹⁴⁸ (1977)	8.5 ± 1.0	Pct Sf = 27. $\pm$ 2.; total $T_{1/2}$ Lazarev ¹²³
Recommended Value $= 8.5 \pm 1.0$ s;		Selected Value

Table LXVII.

Spontaneous Fission Half-life of ^{254}No

Reference Author (Year)	As Reported $T_{1/2}$ / h	Comments
Flerov ¹⁴⁹ (1967)	> 26 .	Pct Sf < 0.06
Sommerville ¹⁴⁰ (1985)	> 30.6	
Tuerler ¹⁵⁰ (1988)	6.1 ± 5.6	Pct Sf = 0.25
Lazarev ¹²⁵ (1989)	8.9 ± 2.5	Pct Sf = 0.17 ± 0.05
Weighted Average $= 8. \pm 2$. h;		Recommended Value

Table LXVIII.

Spontaneous Fission Half-life of ^{256}No

Reference Author (Year)	As Reported $T_{1/2}$ / m	Comments
Ghiorso ¹⁴⁷ (1987)	19.3 ± 3.3	Pct Sf = 0.3
Flerov ¹⁵¹ (1968)	≈ 25 .	Pct Sf = 0.25
Hoffman ¹⁵² (1980)	$9.2 + 0.7 - 1.2$	Sf/ α = 0.0053
Recommended Value $= 9. \pm 1$. m;		Weighted Average

Table LXIX.**Spontaneous Fission Half-life of ^{258}No**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Nurmia ¹⁵³ (1969)	≈ 1.2	Pct Sf = 100.
Hulet ¹⁵⁴ (1989)	1.2 ± 0.2	Pct Sf = 100.
<i>Recommended Value = 1.2 ± 0.2 ms;</i>		<i>Selected Value</i>

Table LXX.**Spontaneous Fission Half-life of ^{259}No**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / h</u>	<u>Comments</u>
Wild ¹⁴⁵ (1982)	$> 10.$	Pct Sf $< 10.$
<i>Recommended Value $> 10.$ h;</i>		<i>Selected Value</i>

Table LXXI.**Spontaneous Fission Half-life of ^{260}No**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Sommerville ¹⁴⁰ (1985)	$106. \pm 8.$	Pct Sf = 100.
<i>Recommended Value = $106. \pm 8.$ ms;</i>		<i>Selected Value</i>

Table LXXII.**Spontaneous Fission Half-life of ^{262}No**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Lougheed ¹⁵⁵ (1988)	5.	Pct Sf = 100.
<i>Recommended Value = 5. ms;</i>		<i>Selected Value</i>

Table LXXIII.**Spontaneous Fission Half-life of ^{252}Lr**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Oganessian ¹⁵⁶ (1976)	$> 100.$	Pct Sf $< 1.$
<i>Recommended Value $> 100.$ s;</i>		<i>Selected Value</i>

Table LXXIV.**Spontaneous Fission Half-life of ^{253}Lr**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Oganessian ¹⁵⁶ (1976)	$> 130.$	Pct Sf $< 1.$
Hessberger ¹⁵⁷ (1985)	$> 7.$	Pct Sf $< 20.$
<i>Recommended Value > 2.2 m;</i>		<i>Selected Value</i>

Table LXXV.

Spontaneous Fission Half-life of ^{254}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{h}$	Comments
Oganessian ¹⁵⁶ (1976)	> 3.6	Pct Sf < 0.1; Total $T_{1/2}$ Hessberger ¹⁵⁷
<i>Recommended Value</i> > 3.6 h;		<i>Selected Value</i>

Table LXXVI.

Spontaneous Fission Half-life of ^{255}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{h}$	Comments
Oganessian ¹⁵⁶ (1976)	> 6.	Pct Sf < 0.1; Total $T_{1/2}$ Eskola ¹⁵⁸
<i>Recommended Value</i> > 6. h;		<i>Selected Value</i>

Table LXXVII.

Spontaneous Fission Half-life of ^{256}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{s}$	Comments
Flerov ¹⁵⁹ (1970)	> 10^5	
<i>Recommended Value</i> > 1.2 d;		<i>Selected Value</i>

Table LXXVIII.

Spontaneous Fission Half-life of ^{257}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{s}$	Comments
Flerov ¹⁵⁹ (1970)	> 10^5	
<i>Recommended Value</i> > 1.2 d;		<i>Selected Value</i>

Table LXXIX.

Spontaneous Fission Half-life of ^{258}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{s}$	Comments
Flerov ¹⁶⁰ (1971)	> 20.	
Gregorich ¹⁶¹ (1992)	> 78.	Pct SF < 5.
<i>Recommended Value</i> > 78. s;		<i>Selected Value</i>

Table LXXX.

Spontaneous Fission Half-life of ^{259}Lr

Reference Author (Year)	As Reported $T_{1/2} / \text{s}$	Comments
Gregorich ¹⁶¹ (1992)	$28. \pm 3.$	Pct SF = $23. \pm 2.$
Hamilton ¹⁶² (1992)	$31. \pm 4.$	$\text{sf}/\alpha = 0.25 \pm 0.03$
<i>Recommended Value</i> = $31. \pm 4. \text{ s};$		<i>Selected Value</i>

Table LXXXI.**Spontaneous Fission Half-life of ^{281}Lr**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / m</u>	<u>Comments</u>
Lougheed ¹⁶³ (1987)	39. $\pm$ 12.	Pct Sf = 100.
<i>Recommended Value = 0.7 $\pm$ 0.2 h;</i>		<i>Selected Value</i>

Table LXXXII.**Spontaneous Fission Half-life of ^{282}Lr**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / m</u>	<u>Comments</u>
Lougheed ¹⁶³ (1987)	2180. $\pm$ 150.	Pct Sf < 10.
<i>Recommended Value > 1.5 d;</i>		<i>Selected Value</i>

Table LXXXIII.**Spontaneous Fission Half-life of $^{253}104$**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / s</u>	<u>Comments</u>
Flerov ¹⁶⁴ (1976)	$\approx$ 3.6	Pct Sf $\approx$ 50.
<i>Recommended Value $\approx$ 3.6 s;</i>		<i>Selected Value</i>

Table LXXXIV.**Spontaneous Fission Half-life of $^{254}104$**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / ms</u>	<u>Comments</u>
Oganessian ¹⁶⁵ (1975)	< 3.	
Ter-Akopyan ¹²² (1975)	0.5 $\pm$ 0.2	Sf/ α > 8.
<i>Recommended Value = 0.5 $\pm$ 0.2 ms;</i>		<i>Selected Value</i>

Table LXXXV.**Spontaneous Fission Half-life of $^{255}104$**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / s</u>	<u>Comments</u>
Flerov ¹⁵⁹ (1970)	$\approx$ 4.	Pct Sf $\approx$ 50.
Oganessian ¹⁶⁵ (1975)	$\approx$ 8.	Pct Sf $\approx$ 50.
Hessberger ¹⁶⁶ (1985)	2.7 $\pm$ 0.5	Pct Sf = 52. $\pm$ 7.
<i>Recommended Value = 2.7 $\pm$ 0.5 s;</i>		<i>Selected Value</i>

Table LXXXVI.**Spontaneous Fission Half-life of $^{256}104$**

<u>Reference</u> <u>Author (Year)</u>	<u>As Reported</u> <u>$T_{1/2}$ / ms</u>	<u>Comments</u>
Oganessian ¹⁶⁷ (1984)	6.9 $\pm$ 0.2	Using Pct Sf = 98. Hessberger ¹⁶⁶
Hessberger ¹⁶⁶ (1985)	7.4 $\pm$ 0.8	
<i>Unweighted Average = 7.2 $\pm$ 0.3 s;</i>		<i>Recommended Value</i>

Table LXXXVII.

Spontaneous Fission Half-life of $^{257}\text{104}$

Reference Author (Year)	As Reported $T_{1/2}$ / s	Comments
Oganessian ¹⁶⁸ (1984)	$\approx 39.$	Pct Sf $\approx 12.$
Sommerville ¹⁴⁰ (1985)	$34. \pm 22.$	Pct Sf = $14. \pm 9.$
	$> 59.$	Pct Sf < $8.,$ using GSI data.
Bemis ¹⁶⁹ (1988)	$196. \pm 25.$	Pct Sf = 2.4 ± 0.3
Recommended Value = 3.3 ± 0.4 m;		Selected Value

Table LXXXVIII.

Spontaneous Fission Half-life of $^{258}\text{104}$

Reference Author (Year)	As Reported $T_{1/2}$ / ms	Comments
Ghiorso ¹⁷⁰ (1969)	$13. \pm 2.$	Pct Sf $\approx 87.,$ Oganessian ¹⁵⁵
Sommerville ¹⁴⁰ (1985)	$15. \pm 3.$	Pct Sf $\approx 87.,$ Oganessian ¹⁵⁵
Weighted Average = $14. \pm 2.$ ms;		Recommended Value

Table LXXXIX.

Spontaneous Fission Half-life of $^{259}\text{104}$

Reference Author (Year)	As Reported $T_{1/2}$ / s	Comments
Druin ¹⁷¹ (1973)	$\approx 46.$	Sf / $\alpha \approx 0.07$
Bemis ¹⁷² (1981)	$48. \pm 35.$	Pct Sf = 6.3 ± 3.7
Sommerville ¹⁴⁰ (1985)	$38. \pm 23.$	Pct Sf = $9. \pm 3.$
Recommended Value = 0.7 ± 0.4 m;		Selected Value

Table XC.

Spontaneous Fission Half-life of $^{260}\text{104}$

Reference Author (Year)	As Reported $T_{1/2}$ / s	Comments
Plerov ¹⁷³ (1984)	$300. \pm 100.$	
Oganessian ¹⁷⁴ (1970)	$100. \pm 50.$	
Druin ¹⁷⁵ (1976)	$80. \pm 20.$	
Druin ¹⁷⁶ (1977)	$76. \pm 8.$	
Nitschke ¹⁷⁷ (1981)	$23. \pm 2.$	
Sommerville ¹⁴⁰ (1985)	20.1 ± 0.7	
Hulet ¹⁵⁴ (1989)	$25.8 \pm 7.$	
Recommended Value = $20. \pm 1.$ ms;		Selected Value

Table XCI.**Spontaneous Fission Half-life of $^{261}\text{104}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Ghiorso ¹⁷⁸ (1970)	> 650.	Pct Sf < 10.
<i>Recommended Value > 11. m;</i>		<i>Selected Value</i>

Table XCII.**Spontaneous Fission Half-life of $^{262}\text{104}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Sommerville ¹⁴⁰ (1985)	47. $\pm$ 5.	Pct Sf = 100.
<i>Recommended Value = 47. $\pm$ 5. ms;</i>		<i>Selected Value</i>

Table XCIII.**Spontaneous Fission Half-life of $^{265}\text{105}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Plerov ¹⁷⁹ (1976)	$\approx$ 8.	Pct Sf $\approx$ 20.
<i>Recommended Value $\approx$ 8. s;</i>		<i>Selected Value</i>

Table XCIV.**Spontaneous Fission Half-life of $^{268}\text{105}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Oganessian ¹⁸⁰ (1983)	> 6.5	Pct Sf < 40.
<i>Recommended Value > 6.5 s;</i>		<i>Selected Value</i>

Table XCV.**Spontaneous Fission Half-life of $^{267}\text{105}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Oganessian ¹⁵⁸ (1976)	$\approx$ 25.	Pct Sf $\approx$ 20.
Hessberger ¹⁵⁷ (1985)	8.2 $\pm$ 6.1	Pct Sf = 17. $\pm$ 11.
<i>Recommended Value = 8. $\pm$ 6. s;</i>		<i>Selected Value</i>

Table XCVI.**Spontaneous Fission Half-life of $^{260}\text{105}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Ghiorso ¹⁸¹ (1970)	> 8.	Pct Sf < 20.
Bemis ¹⁸² (1977)	15.8 $\pm$ 1.7	Pct Sf = 9.6 $\pm$ 0.6
<i>Recommended Value = 16. $\pm$ 2. s;</i>		<i>Selected Value</i>

Table XCVII.**Spontaneous Fission Half-life of ²⁶¹105**

<u>Reference Author (Year)</u>	<u>As Reported T_{1/2} / s</u>	<u>Comments</u>
Ghiorso ¹⁸³ (1971)	> 3.6	Pct Sf < 50.
<i>Recommended Value > 3.6 s;</i>		<i>Selected Value</i>

Table XCVIII.**Spontaneous Fission Half-life of ²⁶²105**

<u>Reference Author (Year)</u>	<u>As Reported T_{1/2} / s</u>	<u>Comments</u>
Ghiorso ¹⁸³ (1971)	> 67.	Pct Sf < 60.
Bemis ¹⁸⁴ (1977)	44. ± 7.	Pct Sf = 78. ± 6.
Druin ¹⁸⁵ (1979)	≈ 59.	Pct Sf ≈ 60.
Gregorich ¹⁸⁶ (1988)	69.	Pct Sf = 49. ± 13.
Kratz ¹⁸⁷ (1989)	67.	Pct Sf = 51. ± 11.
Kratz ¹⁸⁸ (1992)	≥ 102.	Pct Sf ≈ 33., may be due partially to Sf of ²⁶² 104 produced via electron capture
<i>Recommended Value ≥ 1.7 m;</i>		<i>Selected Value</i>

Table XCIX.**Spontaneous Fission Half-life of ²⁶³105**

<u>Reference Author (Year)</u>	<u>As Reported T_{1/2} / s</u>	<u>Comments</u>
Hulet ¹⁸⁹ (1988)	≈ 50.	Pct Sf ≈ 55.
Kratz ¹⁹⁰ (1990)	47. ± 16.	Pct Sf = 57. ± 14.
<i>Recommended Value = 0.8 + 0.1 m;</i>		<i>Selected Value</i>

Table C.**Spontaneous Fission Half-life of ²⁶⁹106**

<u>Reference Author (Year)</u>	<u>As Reported T_{1/2} / s</u>	<u>Comments</u>
Demin ¹⁹¹ (1984)	> 0.1	
Muenzenberg ¹⁹² (1985)	> 2.4	Pct Sf < 20.
<i>Recommended Value > 2.4 s;</i>		<i>Selected Value</i>

Table CI.**Spontaneous Fission Half-life of ²⁸⁰106**

<u>Reference Author (Year)</u>	<u>As Reported T_{1/2} / ms</u>	<u>Comments</u>
Demin ¹⁹¹ (1984)	> 12.5	Pct Sf < 20.
Muenzenberg ¹⁹² (1985)	7.2 ± 4.4	Pct Sf = 50.
<i>Recommended Value = 7. ± 4. ms;</i>		<i>Selected Value</i>

Table CII.**Spontaneous Fission Half-life of $^{261}\text{106}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Demin ¹⁹¹ (1984)	> 0.4	Pct Sf < 20.
Muenzenberg ¹⁹² (1985)	> 2.6	Pct Sf < 10.
<i>Recommended Value > 2.6 s;</i>		<i>Selected Value</i>

Table CIII.**Spontaneous Fission Half-life of $^{263}\text{106}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Druin ¹⁸⁵ (1979)	$\approx$ 1.1	Pct Sf $\approx$ 70.
<i>Recommended Value $\approx$ 1.1 s;</i>		<i>Selected Value</i>

Table CIV.**Spontaneous Fission Half-life of $^{261}\text{107}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / s</u>	<u>Comments</u>
Muenzenberg ¹⁹³ (1989)	> .12	Pct Sf < 10.
<i>Recommended Value > 0.12 s;</i>		<i>Selected Value</i>

Table CV.**Spontaneous Fission Half-life of $^{264}\text{108}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Oganessian ¹⁹⁴ (1984)	> 5.	Armbruster ¹⁹⁵ revision
<i>Recommended Value > 5. ms;</i>		<i>Selected Value</i>

Table CVI.**Spontaneous Fission Half-life of $^{265}\text{108}$**

<u>Reference Author (Year)</u>	<u>As Reported $T_{1/2}$ / ms</u>	<u>Comments</u>
Demin ¹⁹⁸ (1984)	> 20.	Pct Sf < 40.
<i>Recommended Value > 20. ms;</i>		<i>Selected Value</i>

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