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Total and Spontaneous Fission Half-lives of the Uranium and Plutonium Nuclides

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Abstract

The total half-life and the half-life for spontaneous fission are evaluated for the various long-lived nuclides of interest. Recommended values are presented for ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{236}Pu, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{244}Pu. The uncertainties are provided at the 95% confidence limit for each of the recommended values.

I. Introduction

The long-lived nuclides of the uranium and plutonium elements are of interest for their use in nuclear reactors, as well as in certain safeguard applications. The total half-lives for the uranium nuclides were reviewed some time ago[1]. At that time, the only spontaneous fission value which was evaluated was ^{238}U. Recently, the plutonium nuclides were reviewed[2] for both total and fission half-lives.

The general procedure followed in this paper has been to review each of the experiments and revise the published values for the latest estimates of the various parameters used by the original authors. For the case of the total halflives of uranium, only differences from the original work have been discussed. The reference list supplements that given in reference 1.

II. Uranium Isotopes

The only change in the total half-life of the uranium nuclides compared to reference 1 is in the ^{234}U value where Poenitz and Meadows[3] have intercompared 15 ^{235}U samples from 7 labs and obtained an estimated ^{234}U half-life value. They also left out Meadows earlier value[4] as too uncertain.

For the spontaneous fission measurements, only ^{238}U had been investigated in reference 1 and there are a number of additional values in the literature now[5,6,7,8,9,10].

III. Plutonium Isotopes

It can be noted in the various tables in section VI that the uncertainties quoted by some authors are such that exclude many other recent measurements from consideration. Undoubtedly, systematic errors have not been carefully considered in these publications.

IV. Discussion of Results

Although the uranium nuclide total half-lives are in reasonable agreement among the various experiments, except perhaps for ^{232}U, more work in evaluation is required for the plutonium nuclides before we have a similar situation. As a result, the recommended values indicate a larger uncertainty than one might obtain by a simple weighted average of data. This procedure (weighted average) is not considered justified at this point. Work will continue in this area.

V. References

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VI. Tabulated Results

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

Author(Year)	$T_{1/2}$ (10^{13}Years)
Jaffey(51)	8. (5.5)
Segre(52)	> 0.8

Table II Total Half-life of ^{232}U

Author(Year)	$T_{1/2}$ (Years)	Comment
Sellars(54)	73.6 (3.0)	
Chilton(64)	71.7 (0.9)	99.2% enriched sample
Aggarwal(79)	68.90 (0.56)	

Table III Spontaneous Fission Half-life of ^{233}U

Author(Year)	$T_{1/2}$ (10^{17}years)	Comment
Segre(52)	> 2.7	
Aleksandrov(66)	1.2 (0.3)	No mention of correction for ^{232}U. If present to 0.03%, this contribution of ^{232}U would account for discrepancy.
von Gunten(81)	> 2.7	97.11% enriched sample

Table IV Total Half-life of ^{233}U

Author(Year)	$T_{1/2}$ (10^{5}years)
Jaffey(74)	1.591 (0.001)
Vaninbroukx(76)	1.5925 (0.0027)
Geidel'man(79)	1.5937 (0.0033)
Aggarwal(80)	1.5885 (0.0085)

Table V Spontaneous Fission Half-life of ^{234}U

Author(Year)	$T_{1/2}$ (10^{16}years)
Segre(52)	> 0.6
Ghiorso(52)	1.6 (0.7)
von Gunten(81)	1.42 (0.08)

Table VI Total Half-life of ^{234}U

Author(Year)	$T_{1/2}$ (10^{5}years)	Comment
Fleming(52)	2.475 (0.048)	
White(65)	2.47 (0.06)	
Meadows(70)	2.439 (0.072)	Author withdrew data
DeBievre(72)	2.450 (0.006)	
Loumsbury(72)	2.458 (0.012)	
Geidel'man(80)	2.459 (0.008)	
Poenitz(83)	2.457 (0.005)	Mass intercomparison used

Table VII Spontaneous Fission Half-life of ^{235}U

Author(Year)	$T_{1/2}$ (10^{18}years)
Segre(52)	0.18
Aleksandrov(86)	0.35 (0.09)
Greutter(73)	> 1.8
von Gunten(81)	9.8 (2.8)

Table VIII Total Half-life of ^{235}U

Author(Year)	$T_{1/2}$ (10^{8}years)
Nier(39)	7.04 (0.31)
Sayag(51)	6.94 (0.40)
Fleming(52)	7.12 (0.31)
Knight(50)	7.10 (0.32)
Wurger(57)	6.93 (0.27)
White(65)	7.12 (0.18)
Banks(66)	7.02 (+ 0.14 − 0.06)
Deruytter(65)	6.97 (0.19)
Jaffey(71)	7.037 (0.011)

Table IX Spontaneous Fission Half-life of ^{236}U

Author(Year)	$T_{1/2}$ (10^{16}years)	Comment
Jaffey(49)	2. (1.6)	
Conde(71)	2.7 (0.3)	238U/236U = 0.30+-0.03
von Gunten(81)	2.43 (0.13)	
Belenky(83)	2.7 (0.4)	

Table X Total Half-life of ^{236}U

Author(Year)	$T_{1/2}$ (10^{7}years)
Jaffey(51)	2.46 (0.14)
Fleming(52)	2.391 (0.057)
Flynn(72)	2.3422 (0.0031)

Table XII Partial Half-lives of ^{236}Pu

Author(Year)	$T_{1/2}$ (Years)	Decay Mode
Hoffman(57)	2.85 (0.10)	alpha
James(59)	2.7 (0.3)	alpha
Nakanishi(84)	2.87 (0.01)	alpha
Ghiorso(52)	3.4 (1.2)x10^{9}	Spont.Fiss.

Table XIII Alpha Half-life of ^{238}Pu

Author(Year)	$T_{1/2}$ (Years)
Aggarwal(81)	87.98 (0.51)
Sevostijanov(81)	86.54 no uncert.
Diamond(77)	87.71 (0.03)
Polyukov(78)	86.98 (0.39)
Stohm(74)	87.77 (0.023)
Hoffman(57)	86.41 (0.58)
Mech(56)	86 (3.5)
Jaffey(50)	89.59 (0.41)

Table XI Spontaneous Fission Half-life of ^{238}U

Author(Year)	Spec. Act.(10^{-17}years^{-1})
Whitehouse(50)	8.33 (0.52)
Segre(52)	8.60 (0.29)
Fleischer(64)	6.85 (0.20)
Roberts(68)	7.03 (0.11)
Spadavecchia(67)	8.42 (0.10)
von Gunten(69)	8.68 (0.22)
Galliker(70)	8.46 (0.08)
Storzer(70)	8.49 (0.78)
Kleeman(71)	6.8 (0.6)
Thury(71)	8.66 (0.43)
Leme(71)	7.30 (0.18)
Zhan(73)	6.82 (0.55)
Ivanov(75)	7.12 (0.32)
Emma(75)	7.2 (0.2)
Wagner(75)	8.7 (0.6)
Thiel(78)	8.57 (0.42)
Kase(78)	8.22 (0.20)
Popeko(80)	7.9 (0.4)
Hadler(81)	8.6 (0.4)
de Carvalho(82)	11.8 (0.7)
Belenky(83)	8.35 (0.40)
Vartanian(84)	8.23 (0.43)

Table XIV Spontaneous Fission Half-life of ^{238} Pu

Author(Year)	$T_{1/2}$ (10^{10} Years)
Segre(52)	3.8
Jaffey(49)	4.7 (0.4)
Druin(61)	5.1 (0.6)
Hastings(72)	4.77 (0.14)
Gay(75)	4.64 (0.11)

Table XV Half-life of ^{239}Pu

Author(Year)	$T_{1/2}$ (10^4 Years)	Decay Mode
Aleksandrov(75)	2.4060 (0.0038)	Alpha
Glover(75)	2.4115 (0.0080)	"
Jaffey(77)	2.4131 (0.0016)	"
Lucas(78)	2.4112 (0.0016)	"
Gunn(78)	2.4102 (0.0020)	"
Marsh(78)	2.4164 (0.0014)	"
Seabough(78)	2.4101 (0.0020)	"
Prindle(78)	2.4051 (0.0016)	"
Vaninbroukx(78)	2.4100 (0.0030)	"
Brown(81)	2.4088 (0.0051)	"
Segre(52)	5.5 x 10^5 Years	Spont.Fiss.

Table XVI Alpha Half-life of ^{240}Pu

Author(Year)	$T_{1/2}$ (Years)
Inghram(51)	6505 (45)
Butler(56)	6600 (100)
Dokuchaev(59)	6810 (55)
Oetting(67)	6533 (10)
Jaffey(78)	6569 (6)
Rudy(84)	6552.4 (1.7)
Lucas(84)	6552.2 (5.2)
Steinkryger(84)	6571 (7)
Bickman(84)	6574 (8.2)

Table XVII Spontaneous Fission Half-life of ^{240}Pu

Author(Year)	$T_{1/2}$ (10^{11} Years)
Kindermann(53)	1.314 (0.028)
Barclay(54)	1.225 (0.030)
Chamberlain(54)	1.20
Mikheev(59)	1.20
Watt(62)	1.34 (0.015)
Malkin(63)	1.45 (0.02)
White(67)	1.27 (0.05)
Fieldhouse(67)	1.170 (0.025)
Britz-Jorgensen(80)	1.15 (0.03)

Table XVIII Half-life of ^{241}Pu

Author(Year)	$T_{1/2}$ (Years)
Strohm(74)	14.355 (0.007)
Whitehead(77)	14.56 (0.15)
Garner(79)	14.38 (0.07)
Vaninbroukx(78)	14.60 (0.10)
Aggarwal(80)	14.42 (0.09)
Marsh(80)	14.38 (0.06)
Aggarwal(81)	14.52 (0.08)
Aggarwal(81)	14.44 (0.06)
DeBievre(83)	14.33 (0.02)

Table XIX Alpha Half-life of ^{242}Pu

Author(Year)	$T_{1/2}$ (10^5 Years)
Butler(56)	3.849 (0.05)
Butler(56)	3.790 (0.05)
Mech(56)	3.855 (0.100
Benis(69)	3.823 (0.016)
Durham(70)	3.674 (0.07)
Osbourne(76)	3.763 (0.009)
Bulyanitsa(76)	3.702 (0.014)
Meadows(77)	3.708 (0.024)
Aggarwal(79)	3.754 (0.25)

Table XX Spontaneous Fission Half-life of ^{242}Pu

Author(Year)	$T_{1/2}$ (10^{10} Years)
Butler(56)	6.64 (0.10)
Mech(56)	6.80 (0.08)
Druin(61)	6.6 (0.7)
Malkin(63)	7.45 (0.17)
Meadows(77)	6.80 (0.05)

Table XXI Alpha Half-life of ^{244}Pu

Author(Year)	$T_{1/2}$ (10^{7} Years)
Diamond(56)	7.6 (2)
Butler(56)	7.6 (2)
Fields(66)	8.11 (0.26)
Bemis(69)	8.00 (0.11)

Table XXII Spontaneous Fission Half-life of ^{244}Pu

Author(Year)	$T_{1/2}$ (10^{10} Years)
Fields(55)	2.5 (0.8)
Fields(66)	6.82 (0.32)
Gokhberg(77)	6.8 (0.8)

Table XXIII Recommended Half-lives and Uncertainties

Reference Nuclide	$T_{1/2}$ (total) Years	$T_{1/2}$ (spont.fiss.) Years
232U	69.8 (1.0)	8. (6.) x 10^{13}
233U	1.592 (0.002) x 10^{5}	> 2.7 x 10^{17}
234U	2.458 (0.005) x 10^{5}	1.42 (0.08) x 10^{16}
235U	7.037 (0.011) x 10^{8}	9.8 (2.8) x 10^{18}
236U	2.342 (0.0034) x 10^{7}	2.43 (0.13) x 10^{16}
238U	4.468 (0.005) x 10^{9}	8.2 (0.2) x 10^{15}
236Pu	2.9 (0.2)	3.4 (1.2) x 10^{9}
238Pu	87.7 (0.4)	4.7 (0.3) x 10^{10}
239Pu	2.410 (0.005) x 10^{4}	5.5 (no uncert.) x 10^{15}
240Pu	6.56 (0.02) x 10^{3}	1.16 (0.04) x 10^{11}
241Pu	14.4 (0.1)	———
242Pu	3.74 (0.02) x 10^{5}	6.8 (0.1) x 10^{10}
244Pu	8.02 (0.11) x 10^{7}	6.9 (0.3) x 10^{10}

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