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RADIOACTIVE NUCLIDE RADIATION SPECTRA MEASURED WITH SEMICONDUCTOR DETECTORS

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Over the period 1970–1985 radionuclide radiation spectra were measured with semiconductor detectors (SCD), processed and analysed at JINR. The results of investigating 261 radionuclides (750 recorded spectra) were published in two atlases:

1. *Ts.Vylov, G.-J.Beyer, V.M.Gorozhankin, Zh.Zhelev, A.I.Ivanov, R.B.Ivanov, V.G.Kalinnikov, M.Ya.Kuznetsova, N.A.Lebedev, M.A.Mikhailova, A.I.Muminov, A.F.Novgorodov, Yu.V.Norseev, Sh.Omanov, B.P.Osipenko, E.K.Stepanov, K.Thieme, V.G.Chumin, A.F.Shchus', Yu.V.Yushkevich.*
Radioactive Nuclide Radiation Spectra Measured with Semiconductor Detectors.
ZFK-399, Dresden, 1980.

2. *Ts.Vylov, G.-J.Beyer, S.Batsev, V.B.Brudanin, V.M.Gorozhankin, A.I.Ivanov, A.N.Inoyatov, V.G.Kalinnikov, N.A.Lebedev, M.Milanov, A.F.Novgorodov, B.P.Osipenko, N.I.Rukhadze, K.Thieme, V.G.Chumin.*
Spectra of Radioactive Nuclides Radiation, Measured with Semiconductor Detectors (part II).
ZFK-505, Dresden, 1983.

and in the monograph:

Ts.Vylov, V.M.Gorozhankin, Zh.Zhelev, A.I.Ivanov, R.B.Ivanov, V.G.Kalinnikov, M.Ya.Kuznetsova, N.A.Lebedev, M.A.Mikhailova, A.I.Muminov, A.F.Novgorodov, Yu.V.Norseev, Sh.Omanov, B.P.Osipenko, E.K.Stepanov, V.G.Chumin, A.F.Shchus', Yu.V.Yushkevich.
Radioactive Nuclide Radiation Spectra.
Tashkent: FAN, 1980.

An atlas of 145 recorded gamma spectra measured with Ge(Li) and NaJ(Tl) detectors for 73 radionuclides used in nuclear medicine was also published:

Ts.D.Vylov, A.A.Klyuchnikov, A.F.Novgorodov, N.I.Rukhadze.
The Spectrum Atlas of Radionuclides for Medical Purposes.
Kiev, INR, 1988.

This is the electronic version of the two atlases that includes additional 150 recorded spectra for 25 radionuclides. The investigated radioactive radiation sources are listed in Table 1, which also presents half-lives, initial activity production techniques, source preparation technique (column 4: mass separation, 5: evaporation, 6: electrolysis, 7: irradiated target), types of radiation in question, and codes of recorded spectra (columns 8, 9, 10 are α-, β- and γ-radiation respectively). Spectra are retrieved by indicating the corresponding code that contains the following information:

A	Z	α, β, γ	n
xxx	xx	x	x

Here A is the mass number, Z is the nuclear charge; type of radiation: 1 for α, 2 for electrons, 3 for γ; n is the ordinal number of the spectrum. All recorded spectra are arranged in order of increasing A, and in each series of isobars they are arranged in order of increasing Z. In some cases the experimental conditions were such that several radiations were recorded at the same time. The radiation index indicates the decay characteristic for whose investigations the given experiment was designed.

Measurement conditions are indicated in each spectrum. The following notation is used:

АИ (AR)	– annihilation radiation
T1	– time since production of the source
T2	– measurement time
P (R)	– distance between the source and the detector
ФП (Abs)	– absorption filter between the source and the detector
Ф (BG)	– natural radioactive background
OB (SE)	– single escape peak of annihilation gamma quanta
ДВ (DE)	– double escape peak of annihilation gamma quanta
П	– impurity nuclide (in the case of several impurities their ordinal numbers are given)
B	– induction of a uniform magnetic field used to filtrate accompanying radiations

Most of the recorded spectra are given both at the logarithmic and at the linear scale. By and large, the logarithmic scale remarkably reproduces the most characteristic features of the radiation spectrum but, unfortunately, it is inconvenient for planning and examining spectrum details. Therefore, in some cases characteristic fragments are also given at the linear scale. In addition, some measurements were carried out under such conditions that distorting effects had quite a great impact on recorded spectra. It is important to know contribution from these effects when designing and conducting new experiments.

The experimental conditions are detailed in Appendices 1 and 2 (the text part of the published atlases).

Appendix 3 presents a spectral atlas for the medical radionuclides listed in Table 2.

Finally, we point out that this atlas was made over 25 years ago within the framework of the programme YASNAPP (nuclear spectroscopy on the proton beam). From the modern technological point of view it could be made in a more practical and presentable way with retaining all digital information. Unfortunately, the programme like YASNAPP does not exist and thus it is impossible to use expensive proton beams and appropriate radiochemical and mass separation techniques for separation of isotopes. Therefore, some of the spectra given in the atlas are unique and will hardly ever be measured under the same conditions.

The author is thankful to M.G.Kekelidze for his large contribution to the creation of the electronic version of the atlas of radionuclide radiation spectra measured with semiconductor detectors.

DEMO version: http://www.atlas.dubna.ru/; http://www.atlas.jinr.ru/

CD atlas purchase information is available in the Publishing Department of JINR at the address:

Joint Institute for Nuclear Research, Publishing Department, Joliot-Curie Str. 6,
141980 Dubna, Moscow Region.
E-mail: publish@pds.jinr.dubna.su

Table 1.

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{7}Be	53.23 d	Li (p,n)		+					7-4-3-1
^{13}N	9.965 m	^{10}B (α, n)		+					13-7-3-1 13-7-3-2
^{22}Na	2.603 y	Mg (d, 2n)		+					22-11-3-1 22-11-3-2
^{24}Na	15.029 h	Al (p, xp, yn) Na (n,γ)				+ +			24-11-3-1 24-11-3-2
^{26}Al	$7.16 \cdot 10^{6}$ y	Mg (p, n)		+					26-13-3-1 26-13-3-2
^{35}S	87.4 d	S (n,γ)		+				35-16-2-1 35-16-2-2	
^{42}K	12.36 h	Ti (p, xp, yn)	+						42-19-3-1
^{43}K	22.2 h	Ti (p, xp, yn)	+						43-19-3-1 43-19-3-2
^{44}Ti+	47.3 y	Sc (p, 2n)		+					44+-22-3-1 44+-22-3-2 44+-22-3-3
^{45}Ti	3.08 h	Ni (p, xp, yn)		+					45-22-3-1
^{46}Sc	84 d	Sc (n,γ)				+			46-21-3-1 46-21-3-2
^{48}V	15.97 d	Ti (d, 2n)		+					48-23-3-1 48-23-3-2
^{48}Cr	21.56 h	^{46}Ti (α, 2n)		+					48-24-3-1
^{49}V	330 d	Ti (d, n)		+					49-23-3-1 49-23-3-2 49-23-3-3
^{51}Cr	27.702 d	Cr (n,γ)		+					51-24-3-1 51-24-3-2 51-24-3-3
^{52m}Mn	21.1 m	^{52}Fe decay		+					52m-25-3-1 52m-25-3-2 52m-25-3-3
^{52}Fe	8.27 h	Ni (p, xn, yn)		+					52-26-3-1 52-26-3-2 52-26-3-3
^{54}Mn	312.16 d	Cr (d, 2n)		+					54-25-3-1 54-25-3-2 54-25-3-3 54-25-3-4
^{55}Fe	2.72 y	Fe (n, γ)		+					55-26-3-1 55-26-3-2 55-26-3-3 55-26-3-4
^{55}Co	17.53 h	^{56}Fe (p, 2n)		+					55-27-3-1 55-27-3-2
^{56}Mn	2.58 h	Mn (n, γ)				+			56-25-3-1

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{56}Co	78.76 d	Fe (p, n)		+					56-27-3-1 56-27-3-2 56-27-3-3
^{57}Co	271.5 d	Ni (p, γ)		+				57-27-2-1	57-27-3-1 57-27-3-2 57-27-3-3 57-27-3-4 57-27-3-5
^{58}Co	70.79 d	Mn (γ, n)		+					58-27-3-1 58-27-3-2 58-27-3-3
^{59}Fe	44.52 d	Fe (n, γ)		+					59-26-3-1 59-26-3-2
^{60}Co	5.273 d	Co (n, γ)		+					60-27-3-1 60-27-3-2 60-27-3-3
^{64}Cu	12.70 h	Cu (n, γ)				+			64-29-3-1 64-29-3-2
^{65}Zn	243.9 d	Zn (n, γ)		+					65-30-3-1 65-30-3-2 65-30-3-3
^{67}Ga	78.3 h	Cu (γ, 2n)	+					67-31-2-1 67-31-2-2	67-31-3-1 67-31-3-2
^{68}Ge+	287 d	Zn (γ , 2n)		+					68+-32-3-1 68+-32-3-2
^{69m}Zn	13.76 h	^{68}Zn (n, γ)		+					69m-30-3-1 69m-30-3-2
^{72}Ga	14.1 h	Ga (n, γ)				+			72-31-3-1 72-31-3-2
^{75}Se	119.8 d	Se (n, γ)		+					75-34-3-1 75-34-3-2 75-34-3-3
^{79}Rb	23.0 m	Zr (p, xp, yn)	+					79-37-2-1	79-37-3-1 79-37-3-2 79-37-3-3
^{80}Sr+	1.8 h	Zr (p, xp, yn)	+						80+-38-3-1
^{81}Rb	4.58 h	Zr (p, xp, yn)	+					81-37-2-1	81-37-3-1 81-37-3-2 81-37-3-3
^{81}Sr	25 m	Zr (p, xp, yn)	+						81-38-3-1 81-38-3-2
^{82}Br	35.34 h	Br (n, γ)		+					82-35-3-1 82-35-3-2 82-35-3-3 82-35-3-4
^{82}Rb	1.273 m	^{82}Sr decay							82-37-3-1 82-37-3-2

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{82m}Rb	6.3 h	Zr (p, xp, yn)	+						82m-37-3-1 82m-37-3-2
^{82}Sr+	25 d	Zr (p, xp, yn)	+					82+-38-2-1	82+-38-3-1 82+-38-3-2
^{83}Rb	86.2 d	Zr (p, xp, yn)	+					83-37-2-1 83-37-2-2	83-37-3-1 83-37-3-2
^{83}Sr	33 h	Zr (p, xp, yn)	+						83-38-3-1 83-38-3-2
^{84}Rb	34.5 d	Zr (p, xp, yn)	+						84-37-3-1
^{84m}Rb	21 m	Zr (p, xp, yn)	+						84m-37-3-1
^{85}Sr	64.84 d	Zr (p, xp, yn)	+					85-38-2-1	85-38-3-1
^{85m}Sr	67.7 m	Zr (p, xp, yn)	+						85m-38-3-1
^{85}Y	4.9 h	Zr (p, xp, yn)	+						85-39-3-1 85-39-3-2 85-39-3-3
^{86}Rb	18.8 d	^{85}Rb (n, γ)		+					86-37-3-1 86-37-3-2
^{86}Y	14.74 h	Zr (p, xp, yn)	+						86-39-3-1 86-39-3-2 86-39-3-3
^{87m}Sr	2.803 h	^{87}Y decay							87m-38-3-1 87m-38-3-2
^{87}Y	80.3 h	Zr (p, xp, yn)	+						87-39-3-1
^{87m}Y	13 h	Zr (p, xp, yn)	+					87m-39-2-1	87m-39-3-1 87m-39-3-2
^{88}Y	106.6 d	Sr (p, n)		+					88-39-3-1 88-39-3-2 88-39-3-3
^{88}Zr	83.4 d	Zr (p, xp, yn)	+						88-40-3-1 88-40-3-2
^{91}Y	58.5 d	fission		+					91-39-3-1 91-39-3-2
^{93}Mo	$3.5 \cdot 10^3$ y	Nb (p, n)		+					93-42-3-1 93-42-3-2
^{95}Zr+	64.0 d	Zr (n, γ)		+					95+-40-3-1 95+-40-3-2 95+-40-3-3
^{97}Ru	2.88 d	^{96}Ru (n, γ)		+					97-44-3-1 97-44-3-2
^{99}Mo+	66.0 h	Mo (n, γ)				+			99+-42-3-1 99+-42-3-2
^{99m}Tc	6.0 h	^{99}Mo decay		+					99m-43-3-1 99m-43-3-2 99m-43-3-3 99m-43-3-4

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{101}Rh	3 y	Ru (p, n)			+				101-45-3-1 101-45-3-2 101-45-3-3
^{101m}Rh	4.34 d	Ru (p, n)			+				101m-45-3-1 101m-45-3-2
^{102m}Rh	2.9 y	Ru (p, n)			+				102m-45-3-1 102m-45-3-2
^{106}Ru+	368 d	fission	+	+					106+-44-3-1 106+-44-3-2
^{107}Cd	6.5 h	^{107}In decay	+						107-48-3-1 107-48-3-2
^{107}In	32.4 m	Ta (p, xp, yn)	+						107-49-3-1 107-49-3-2 107-49-3-3 107-49-3-4
^{108m}Ag+	127 y	Ag (n, γ)				+			108m+-47-3-1 108m+-47-3-2 108m+-47-3-3 108m+-47-3-4 108m+-47-3-5
^{108}In	40 m	Ta (p, xp, yn)	+						108-49-3-1 108-49-3-2 108-49-3-3 108-49-3-4
^{109}Cd	453.2 d	Ag (γ, 2n)		+ +				109-48-2-1	109-48-3-1 109-48-3-2 109-48-3-3 109-48-3-4
^{109}In	4.2 h	Ta (p, xp, yn)	+						109-49-3-1 109-49-3-2 109-49-3-3 109-49-3-4
^{110m}Ag+	250.4 d	Ag (n, γ)		+					110m+-47-3-1 110m+-47-3-2 110m+-47-3-3
^{110}In	69.1 m	Ta (p, xp, yn)	+						110-49-3-1 110-49-3-2 110-49-3-3 110-49-3-4
^{111}In	2.83 d	Ta (p, xp, yn)	+						111-49-3-1 111-49-3-2 111-49-3-3 111-49-3-4
^{113}Sn	115.1 d	Sn (n, γ)		+					113-50-3-1 113-50-3-2 113-50-3-3 113-50-3-4 113-50-3-5 113-50-3-6

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{116m}In	54 m	In (n, γ)				+			116m-49-3-1
^{117}Sb	2.8 h	Ta (p, xp, yn)	+						117-51-3-1 117-51-3-2
^{118}Sb	3.6 m	^{118}Te decay		+					118-51-3-1 118-51-3-2
^{120}Xe	40 m	Cs (p, xp, yn)	+						120-54-3-1
^{121}Te	16.8 d			+					121-52-3-1
^{121}I	2.12 h	^{121}Xe decay		+					121-53-3-1 121-53-3-2
^{121}Xe	38.8 m	Cs (p, xp, yn)	+						121-54-3-1 121-54-3-2
^{122}Xe	20.1 h	Cs (p, xp, yn)	+					122+-54-2-1	122+-54-3-1 122+-54-3-2
^{123}I	13.2 h	^{123}Xe decay		+					123-53-3-1
^{123}Xe	2.08 h	Cs (p, xp, yn)	+					123-54-2-1 123-54-2-2	
^{124}Sb	60.20 d	Sb (n, γ)		+					124-51-3-1 124-51-3-2
^{125}Sb	2.758 y	^{125}Sn decay		+					125-51-3-1 125-51-3-2 125-51-3-3
^{125m}Tl	57.40 d	^{125}Sb decay		+					125m-52-3-1 125m-52-3-2
^{125}I	60.04 d			+					125-53-3-1 125-53-3-2
^{125}Xe	16.8 h	Cs (p, xp, yn)	+					125-54-2-1	125-54-3-1 125-54-3-2 125-54-3-3
^{125}Cs	45 m	Ta (p, xp, yn)	+						125-55-3-1 125-55-3-2 125-55-3-3 125-55-3-4
^{127}Xe	36.4 d	Cs (p, xp, yn)	+						127-54-3-1 127-54-3-2 127-54-3-3
^{127}Cs	6.25 h	Ta (p, xp, yn)	+						127-55-3-1 127-55-3-2
^{128}I	25 m	I (n, γ)				+			128-53-3-1
^{128}Ba+	2.43 d	La (p, xp, yn)	+					128+-56-2-1	128+-56-3-1 128+-56-3-2
^{129}Cs	32.06 h	Ta (p, xp, yn)	+						129-55-3-1 129-55-3-2
^{130}Ce+	25 m	Gd (p, xp, yn)	+						130+-58-3-1

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{131}I	8.054 d	fission		+					131-53-3-1 131-53-3-2 131-53-3-3 131-53-3-4
^{131m}Xe	11.97 d	Cs (p, xp, yn)	+						131m-54-3-1
^{131}Ba	11.5 d	La (p, xp, yn)	+					131-56-2-1 131-56-2-2 131-56-2-3	131-56-3-1 131-56-3-2
^{131}La	59 m	Gd (p, xp, yn)	+					131-57-2-1 131-57-2-2	131-57-3-1 131-57-3-2
^{132}La	4.5 h	Gd (p, xp, yn)	+						132-57-3-1 132-57-3-2 132-57-3-3 132-57-3-4
^{132}Cs	6.479 d	Gd (p, xp, yn)		+					132-55-3-1
^{132}Ce	4.2 h	Gd (p, xp, yn)	+						132-58-3-1 132-58-3-2 132-58-3-3
^{133m}Xe	2.2 d	Gs (p, xp, yn)	+						133m-54-3-1
^{133}Ba	10.73 y	Ba (n, γ)		+					133-56-3-1 133-56-3-2 133-56-3-3 133-56-3-4
^{133m}Ba	38.6 h	La (p, xp, yn)	+					133m-56-2-1	133m-56-3-1
^{133}La	4.0 h	Gd (p, xp, yn)	+					133-57-2-1	133-57-3-1 133-57-3-2 133-57-3-3
^{133}Ce	5.4 h	Gd (p, xp, yn)	+						133-58-3-1 133-58-3-2 133-58-3-3 133-58-3-4
^{134m}Cs	2.91 h	^{133}Cs (n, γ)							134m-55-3-1
^{134}Cs	2.062 y	Cs (n, γ)		+					134-55-3-1 134-55-3-2 134-55-3-3 134-55-3-4
$^{134}Ce+$	72 h	Gd (p, xp, yn)	+						134+-58-3-1 134+-58-3-2
^{135}Xe	9.17 h	Gs (p, xp, yn)	+						135-54-3-1 135-54-3-2
^{135m}Ba	28.7 h	La (p, xp, yn)	+					135m-56-2-1	135m-56-3-1
^{135}La	19.4 h	Gd (p, xp, yn)	+						135-57-3-1 135-57-3-2 135-57-3-3

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{135}Ce	17.0 h	Gd (p, xp, yn)	+					135-58-2-1 135-58-2-2	135-58-3-1 135-58-3-2 135-58-3-3 135-58-3-4
$^{136}Nd+$	50.7 m	Gd (p, xp, yn)	+					136+-60-2-1	136+-60-3-1 136+-60-3-2 136+-60-3-3
^{137}Cs	30.18 y	Cs (n, γ)	+	+				137-55-2-1 137-55-2-2 137-55-2-3	137-55-3-1 137-55-3-2 137-55-3-3
^{137m}Ba	2.552 m	^{137}Cs decay							137m-56-3-1 137m-56-3-2
^{137m}Ce	34.4 h	Gd (p, xp, yn)	+						137m-58-3-1 137m-58-3-2 137m-58-3-3 137m-58-3-4
^{137}Nd	38.0 m	Gd (p, xp, yn)	+						137-60-3-1
^{138m}Pr	2.02 h	Gd (p, xp, yn)	+					138m-59-2-1	138m-59-3-1 138m-59-3-2
$^{138}Nd+$	5.1 h	Gd (p, xp, yn)	+					138+-60-2-1	138+-60-3-1 138+-60-3-2
^{139}Ce	137.64 d	La (d, 2n)	+	+ +				139-58-2-1 139-58-2-2	139-58-3-1 139-58-3-2 139-58-3-3 139-58-3-4
^{139}Pr	4.5 h	Gd (p, xp, yn)	+					139-59-2-1	139-59-3-1 139-59-3-2
$^{139m}Nd+$	5.5 h	Gd (p, xp, yn)	+					139m+-60-2-1 139m+-60-2-2	139m+-60-3-1 139m+-60-3-2
$^{140}Ba+$	12.79 d	U (n, f)	+	+				140+-56-2-1 140+-56-2-2	140+-56-3-1 140+-56-3-2 140+-56-3-3
^{140}La	40.24 h	^{140}Ba decay	+						140-57-3-1 140-57-3-2
$^{140}Nd+$	3.38 d	Gd (p, xp, yn)	+						140+-60-3-1 140+-60-3-2
^{141}Ce	32.50 d	Ce (n, γ)	+					141-58-2-1	141-58-3-1
^{141}Nd	2.5 h	Gd (p, xp, yn)	+						141-60-3-1 141-60-3-2
^{141}Sm	11.3 m	Ta (p, xp, yn)	+						141-62-3-1 141-62-3-2
^{142}Pr	19.2 h	Gd (p, xp, yn)	+					142-59-2-1	142-59-3-1
^{143}Pm	265 d	Er (p, xp, yn)	+						143-61-3-1 143-61-3-2 143-61-3-3 143-61-3-4

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{144}Ce+	284.8 d	U (n, f)		+					144+-58-3-1 144+-58-3-2 144+-58-3-3 144+-58-3-4
^{144}Pm	1.0 y	Er (p, xp, yn)	+						144-61-3-1 144-61-3-2 144-61-3-3 144-61-3-4
^{145}Sm	340 d	Er (p, xp, yn)	+					145-62-2-1	145-62-3-1 145-62-3-2 145-62-3-3
^{145}Eu	5.93 d	Er (p, xp, yn)	+					145-63-2-1 145-63-2-2 145-63-2-3 145-63-2-4	145-63-3-1 145-63-3-2 145-63-3-3 145-63-3-4
^{145}Gd	21.8 m	Ta (p, xp, yn)	+						145-64-3-1
^{146}Pm	5.53 y	Er (p, xp, yn)	+						146-61-3-1 146-61-3-2 146-61-3-3 146-61-3-4
^{146}Eu	4.65 d	Er (p, xp, yn)	+					146-63-2-1 146-63-2-2 146-63-2-3	146-63-3-1 146-63-3-2
^{146}Gd	48.3 d	Er (p, xp, yn)	+					146-64-2-1	146-64-3-1 146-64-3-2
^{147}Nd	10.98 d	Nd (n, γ)		+					147-60-3-1 147-60-3-2 147-60-3-3 147-60-3-4
^{147}Eu	24 d	Er (p, xp, yn)	+					147-63-2-1 147-63-2-2 147-63-2-3	147-63-3-1 147-63-3-2 147-63-3-3
^{147}Gd	38.1 h	Er (p, xp, yn)	+					147-64-2-1 147-64-2-2	147-64-3-1 147-64-3-2 147-64-3-3 147-64-3-4
^{147}Tb	1.61 h	Ta (p, xp, yn)	+						147-65-3-1 147-65-3-2 147-65-3-3
^{148m}Pm	41.3 d	Er (p, xp, yn)	+						148m-61-3-1 148m-61-3-2
^{148}Eu	54 d	Er (p, xp, yn)	+					148-63-2-1 148-63-2-2	148-63-3-1 148-63-3-2 148-63-3-3 148-63-3-4
^{148}Gd	90 y	Er (p, xp, yn)	+				148-64-1-1		
^{148}Tb	70 m	Ta (p, xp, yn)	+					148-65-2-1	148-65-3-1 148-65-3-2

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{149}Pm	53.1 h	Ta (p, xp, yn)	+						149-61-3-1 149-61-3-2 149-61-3-3
^{149}Eu	91.3 d	Er (p, xp, yn)	+					149-63-2-1	149-63-3-1 149-63-3-2
^{149}Gd	9.5 d	Er (p, xp, yn)	+					149-64-2-1 149-64-2-2 149-64-2-3	149-64-3-1 149-64-3-2 149-64-3-3 149-64-3-4
^{149}Tb	4.1 h	Ta (p, xp, yn)	+				149-65-1-1		149-65-3-1 149-65-3-2
^{150}Tb	3.5 h	Ta (p, xp, yn)	+				150-65-1-1		150-65-3-1 150-65-3-2
^{151}Pm	28 h	Er (p, xp, yn)	+						151-61-3-1 151-61-3-2 151-61-3-3
^{151}Gd	120 d	Er (p, xp, yn) Gd (n, γ)	+			+		151-64-2-1	151-64-3-1 151-64-3-2 151-64-3-3 151-64-3-4 151-64-3-5 151-64-3-6 151-64-3-7
^{151}Tb	17.6 h	Ta (p, xp, yn)	+					151-65-2-1 151-65-2-2 151-65-2-3	151-65-3-1 151-65-3-2 151-65-3-3 151-65-3-4
^{151}Dy	17 m	Ta (p, xp, yn)	+						151-66-3-1 151-66-3-2
^{152}Eu	13.60 y	Eu (n, γ)	+					152-63-2-1 152-63-2-2 152-63-2-3	152-63-3-1 152-63-3-2 152-63-3-3 152-63-3-4
^{152m}Eu	9.3 h	Eu (n, γ)				+			152m-63-3-1 152m-63-3-2
^{152}Tb	17.5 h	Ta (p, xp, yn)	+					152-65-2-1 152-65-2-2 152-65-2-3	152-65-3-1 152-65-3-2
^{152}Dy	2.4 h	Ta (p, xp, yn)	+						152-66-3-1
^{153}Gd	241.6 d	Ta (p, xp, yn)	+					153-64-2-1	153-64-3-1 153-64-3-2 153-64-3-3 153-64-3-4

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{153}Tb	2.34 d	Ta (p, xp, yn)	+					153-65-2-1	153-65-3-1 153-65-3-2 153-65-3-3 153-65-3-4 153-65-3-5 153-65-3-6 153-65-3-7 153-65-3-8
^{153}Dy	6.29 h	Ta (p, xp, yn)	+					153-66-2-1 153-66-2-2	153-66-3-1 153-66-3-2
^{154}Eu	8.5 y	Eu (n, γ)	+						154-63-3-1 154-63-3-2 154-63-3-3 154-63-3-4
^{154}Tb	21.4 h	Ta (p, xp, yn)	+						154-65-3-1 154-65-3-2 154-65-3-3
^{155}Eu	4.96 y	^{155}Sm decay	+						155-63-3-1 155-63-3-2 155-63-3-3 155-63-3-4
^{155}Tb	5.32 d	Ta (p, xp, yn)	+					155-65-2-1 155-65-2-2 155-65-2-3	155-65-3-1 155-65-3-2 155-65-3-3
^{155}Dy	9.59 h	Ta (p, xp, yn)	+					155-66-2-1	155-66-3-1 155-66-3-2
^{155}Ho	48 m	Ta (p, xp, yn)	+						155-67-3-1 155-67-3-2
^{155}Er	5.3 m	Ta (p, xp, yn)	+						155-68-3-1
^{156}Eu	15.2 d	^{156}Sm decay	+						156-63-3-1 156-63-3-2 156-63-3-3
^{156}Tb	5.35 d	Ta (p, xp, yn)	+					156-65-2-1	156-65-3-1 156-65-3-2 156-65-3-3 156-65-3-4
^{156}Ho	55 m	Ta (p, xp, yn)	+					156-67-2-1	156-67-3-1 156-67-3-2 156-67-3-3
^{157}Tb	150 y	Ta (p, xp, yn)	+						157-65-3-1
^{157}Dy	8.1 h	Ta (p, xp, yn)	+					157-66-2-1 157-66-2-2	157-66-3-1 157-66-3-2
^{157}Ho	12.6 m	Ta (p, xp, yn)	+						157-67-3-1 157-67-3-2 157-67-3-3
^{157}Er	25 m	Ta (p, xp, yn)	+						157-68-3-1 157-68-3-2

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{158}Tb	150 y								158-65-3-1 158-65-3-2 158-65-3-3 158-65-3-4 158-65-3-5
^{158}Ho	11 m	Ta (p, xp, yn)	+					158-67-2-1	158-67-3-1 158-67-3-2
^{158}Er	2.3 h	Ta (p, xp, yn)	+						158-68-3-1
^{159}Gd	18.48 h	Ta (p, xp, yn)	+						159-64-3-1
^{159}Dy	144.4 d	Ta (p, xp, yn)	+						159-66-3-1
^{159}Ho	33 m	Ta (p, xp, yn)	+					159-67-2-1 159-67-2-2 159-67-2-3	159-67-3-1 159-67-3-2 159-67-3-3
^{160}Tb	72.3 d	Tb (n, γ)	+	+					160-65-3-1 160-65-3-2 160-65-3-4 160-65-3-5 160-65-3-6 160-65-3-7 160-65-3-3
^{160m}Ho	5.0 h	Ta (p, xp, yn)	+					160m-67-2-1	160m-67-3-1 160m-67-3-2 160m-67-3-3 160m-67-3-4
^{160}Er	28.6 h	Ta (p, xp, yn)	+					160-68-2-1	160-68-3-1 160-68-3-2
^{161}Tb	6.90 d	Ta (p, xp, yn)	+						161-65-3-1 161-65-3-2
^{161}Ho	2.5 h	Ta (p, xp, yn)	+					161-67-2-1 161-67-2-2	161-67-3-1 161-67-3-2
^{161}Er	3.1 h	Ta (p, xp, yn)	+						161-68-3-1 161-68-3-2
^{162}Ho	15 m	Ta (p, xp, yn)	+						162-67-3-1
^{163}Er	75 m	Ta (p, xp, yn)	+						163-68-3-1
^{163}Tm	1.81 h	Ta (p, xp, yn)	+					163-69-2-1 163-69-2-2 163-69-2-3 163-69-2-4	163-69-3-1 163-69-3-2 163-69-3-3 163-69-3-4
^{164}Ho	29 m	Ta (p, xp, yn)	+						164-67-3-1
^{164}Yb	75.8 m	Ta (p, xp, yn)	+						164-70-3-1
^{165}Er	10.3 h	Ta (p, xp, yn)	+						165-68-3-1
^{165}Tm	30.06 h	Ta (p, xp, yn)	+					165-69-2-1 165-69-2-2 165-69-2-3 165-69-2-4 165-69-2-5	165-69-3-1 165-69-3-2 165-69-3-3 165-69-3-4

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{166}Ho	26.7 h	Ho (n, γ)				+			166-67-3-1 166-67-3-2
^{166}Tm	7.70 h	Ta (p, xp, yn)	+					166-69-2-1	166-69-3-1 166-69-3-2
^{166}Yb	56.7 h	Ta (p, xp, yn)	+					166-70-2-1	166-70-3-1 166-70-3-2 166-70-3-3
^{167}Tm	9.25 d	Ta (p, xp, yn)	+					167-69-2-1	167-69-3-1 167-69-3-2 167-69-3-3
^{167}Yb	17.7 m	Ta (p, xp, yn)	+						167-70-3-1
^{167}Lu	55 m	Ta (p, xp, yn)	+						167-71-3-1
^{168}Tm	93.1 d	Ta (p, xp, yn)	+						168-69-3-1 168-69-3-2
^{169}Er	9.40 d	Er (n, γ)	+						169-68-3-1 169-68-3-2
^{169}Yb	32.00 d	Ta (p, xp, yn)	+					169-70-2-1 169-70-2-2 169-70-2-3 169-70-2-4	169-70-3-1
^{169}Lu	1.42 d	Ta (p, xp, yn)	+					169-71-2-1	169-71-3-1 169-71-3-2 169-71-3-3
^{170}Tm	128.6 d	Tm (n, γ)		+				170-69-2-1	170-69-3-1 170-69-3-2 170-69-3-3 170-69-3-4
^{170}Lu	2.0 d	Ta (p, xp, yn)	+					170-71-2-1	170-71-3-1 170-71-3-2 170-71-3-3 170-71-3-4 170-71-3-5 170-71-3-6
^{171}Lu	8.22 d	Ta (p, xp, yn)	+					171-71-2-1 171-71-2-2 171-71-2-3 171-71-2-4 171-71-2-5 171-71-2-6	171-71-3-1 171-71-3-2 171-71-3-3
^{172}Lu	6.7 d	Ta (p, xp, yn)	+					172-71-2-1 172-71-2-2 172-71-2-3 172-71-2-4 172-71-2-5 172-71-2-6 172-71-2-7	172-71-3-1 172-71-3-2 172-71-3-3

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{172}Hf	1.87 y	Ta (p, xp, yn)		+					172-72-3-1 172-72-3-2 172-72-3-3 172-72-3-4 172-72-3-5
^{173}Lu	1.37 y	Ta (p, xp, yn)	+					173-71-2-1 173-71-2-2	173-71-3-1 173-71-3-2 173-71-3-3 173-71-3-4 173-71-3-5
^{174g}Lu	3.31 y	Ta (p, xp, yn)	+						174g-71-3-1 174g-71-3-2 174g-71-3-3 174g-71-3-4
^{174m}Lu+	142 d	Ta (p, xp, yn)	+						174m+-71-3-1 174m+-71-3-2
^{175}Hf	70 d	Hf (n, γ)	+						175-72-3-1
^{176}Lu	$3.3 \cdot 10^{10}$ y	natural				+			176-71-3-1
^{176m}Lu	3.68 h	Ta (p, xp, yn)	+						176m-71-3-1
^{177}Lu	6.71 d	Lu (n, γ)	+	+					177-71-3-1 177-71-3-2 177-71-3-3 177-71-3-4
^{177m}Lu	161 d	Ta (p, xp, yn)	+						177m-71-3-1 177m-71-3-2
^{178}Ta	9.25 m								178-73-3-1 178-73-3-2
^{181}Hf	42.38 d	Hf (n, γ)		+					181-72-3-1 181-72-3-2 181-72-3-3 181-72-3-4
^{181}W	121.2 d	W (n, γ)		+					181-74-3-1
^{182}Ta	115.0 d	Ta (n, γ)			+	+		182-73-2-1	182-73-3-1 182-73-3-2 182-73-3-3
^{183}Re	71 d	Ta (γ , 2n)		+					183-75-3-1 183-75-3-2 183-75-3-3 183-75-3-4
^{185}Os	93.6 d			+					185-76-3-1
^{187}W	23.9 h	W (n, γ)				+			187-74-3-1
^{192}Ir	71.08 d	Ir (n, γ)		+					192-77-3-1 192-77-3-2 192-77-3-3 192-77-3-4

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{198}Au	2.695 d	Au (n, γ)				+			198-79-3-1 198-79-3-2 198-79-3-3 198-79-3-4
^{202}Tl	12.24 d								202-81-3-1 202-81-3-2
^{202}Po	45.0 m	Th (p, xp, yn)	+					202-84-2-1 202-84-2-2	202-84-3-1 202-84-3-2
^{203}Hg	46.73 d	Hg (n, γ)		+					203-80-3-1 203-80-3-2 203-80-3-3 203-80-3-4 203-80-3-5
^{203}Pb	52.1 h	Th (p, xp, yn)	+					203-82-2-1	
^{203}Bi	11.76 h	Th (p, xp, yn)	+						203-83-3-1
^{203}Po	37 m	Th (p, xp, yn)	+						203-84-3-1
^{204}Bi	11.3 h	Th (p, xp, yn)	+					204-83-2-1	204-83-3-1
^{204}Po	3.52 h	Th (p, xp, yn)	+					204-84-2-1 204-84-2-2 204-84-2-3	204-84-3-1 204-84-3-2
^{205}Bi	15.31 d	Th (p, xp, yn)	+						205-83-3-1 205-83-3-2 205-83-3-3 205-83-3-4 205-83-3-5
^{205}Po	1.8 h	Th (p, xp, yn)	+						205-84-3-1
^{205}At	26.2 m	Th (p, xp, yn)	+					205-85-2-1	205-85-3-1 205-85-3-2
^{206}Bi	6.24 d								206-83-3-1 206-83-3-2 206-83-3-3
^{206}Po	8.8 d	Th (p, xp, yn)	+					206-84-2-1	206-84-3-1 206-84-3-2
^{206}At	31.4 m	Th (p, xp, yn)	+						206-85-3-1
^{207}Bi	33.4 y			+				207-83-2-1 207-83-2-2 207-83-2-3 207-83-2-4 207-83-2-5	207-83-3-1 207-83-3-2 207-83-3-3
^{207}Po	5.84 h	Th (p, xp, yn)	+				207-84-1-1	207-84-2-1 207-84-2-2	207-84-3-1
^{207}At	1.8 h	Th (p, xp, yn)	+					207-85-2-1 207-85-2-2	207-85-3-1 207-85-3-2
^{208}At	1.63 h	Th (p, xp, yn)	+						208-85-3-1 208-85-3-2

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{208}Rn	24.4 m	Th (p, xp, yn)	+						208-86-3-1 208-86-3-2 208-86-3-3
^{209}At	5.5 h	Th (p, xp, yn)	+				209-85-1-1	209-85-2-1	209-85-3-1 209-85-3-2
^{209}Rn	30 m	Th (p, xp, yn)	+					209-86-2-1	209-86-3-1
^{210}Bi	5.01 d	Bi (n, γ)				+			210-83-3-1
^{210}At	8.3 h	Th (p, xp, yn)	+				210-85-1-1	210-85-2-1	210-85-3-1 210-85-3-2
^{210}Rn	2.4 h	Th (p, xp, yn)	+					210-86-2-1	210-86-3-1 210-86-3-2
^{211}At	7.2 h	Th (p, xp, yn)	+				211-85-1-1		
^{211}Rn	14.6 h	Th (p, xp, yn)	+				 211-86-2-2	211-86-2-1 211-86-3-2	211-86-3-1
^{212}Pb	10.64 h	^{224}Ra decay	+				212-82-1-1		
^{212}Fr	19.3 m	Th (p, xp, yn)	+						212-87-3-1
^{221}Rn	25 m	Th (p, xp, yn)	+						221-86-3-1
^{222}Fr	14.8 m	Th (p, xp, yn)	+						222-87-3-1
^{223}Ra	11.43 d		+				223-88-1-1		223-88-3-1 223-88-3-2 223-88-3-3
^{224}Rn	1.9 h	Th (p, xp, yn)	+					224-86-2-1	224-86-3-1 224-86-3-2
^{224}Ra	3.64 d	U (p, xp, yn)	+				224-88-1-1	224-88-2-1	224-88-3-1
^{225}Ra	14.8 d	U (p, xp, yn)	+				225-88-1-1		225-88-3-1
^{225}Ac	10.0 d	Th (p, xp, yn)	+				225-89-1-1		225-89-3-1
^{226}Ra	1600 y	natural		+			226-88-1-1 226-88-1-2 226-88-1-3		226-88-3-1 226-88-3-2 226-88-3-3 226-88-3-4 226-88-3-5 226-88-3-6
^{226}Ac	29 h	Th (p, xp, yn)	+					226-89-2-1	226-89-3-1
^{227}Ac	21.8 y		+				227-89-1-1 227-89-1-2		227-89-3-1 227-89-3-2
^{227}Th	18.72 d			+					227-90-3-1
$^{228}Th+$	1.913 y			+					228+-90-3-1 228+-90-3-2
^{231}Pa	$3.25 \cdot 10^4$ y			+					231-91-3-1 231-91-3-2 231-91-3-3

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
^{233}Pa	27.0 d	^{233}Th decay		+					233-91-3-1 233-91-3-2 233-91-3-3 233-91-3-4
^{233}U	$1.59 \cdot 10^5$ y			+			233-92-1-1 233-92-1-2		233-92-3-1 233-92-3-2 233-92-3-3 233-91-3-5
^{235}U	$7.04 \cdot 10^8$ y			+					235-92-3-1 235-92-3-2
^{237}Np	$2.14 \cdot 10^6$ y		+						237-93-3-1 237-93-3-2 237-93-3-3
^{238}U	$4.47 \cdot 10^9$ y					+			238-92-3-1 238-92-3-2 238-92-3-3 238-92-3-4
^{238}Np	50.8 h	^{237}Np (n, γ)				+			238-93-3-1 238-93-3-2 238-93-3-3 238-93-3-4
^{238}Pu	87.74 y			+			238-94-1-1 238-94-1-2 238-94-1-3		238-94-3-1 238-94-3-2
^{239}Np	2.347 d	^{239}U decay				+			239-93-3-1 239-93-3-2 239-93-3-3 239-93-3-4 239-93-3-5 239-93-3-6
^{239}Pu	24113 y			+		+	239-94-1-1 239-94-1-2		239-94-3-1 239-94-3-2 239-94-3-3
^{241}Am	432.1 y			+ +			241-95-1-1		241-95-3-1 241-95-3-2 241-95-3-3 241-95-3-4 241-95-3-5
^{242m}Am	152 y			+			242m-95-1-1		242m-95-3-1 242m-95-3-2 242m-95-3-3
^{245}Cm	8532 y			+					245-96-3-1 245-96-3-2 245-96-3-3 245-96-3-4 245-96-3-5
^{249}Cf	350.6 y			+					249-98-3-1 249-98-3-2 249-98-3-3

Table 1. (cont.)

Nuclide	Half-life	Method of production	Source preparation				Plate number		
							α	e	γ
1	2	3	4	5	6	7	8	9	10
Th		natural				+			xxx-90-3-1 xxx-90-3-2
X									xxx-xx-3-1 xxx-xx-3-2 xxx-xx-3-3 xxx-xx-3-4 xxx-xx-3-5 xxx-xx-1-1

Table 2.

Nuclide	Half-life	Decay	Ge, Si	NaJ(Tl)
1	2	3	4	5
^{7}Be	53.23 (8) d	EC	7-4-1	7-4-2
^{13}N	9.961 (5) m	EC	13-7-1	13-7-2
^{18}F	109.800 (5) m	EC	18-9-1	18-9-2
^{22}Na	2.602 (1) y	EC, β^+	22-11-1	22-11-2
^{24}Na	14.959 (1) h	β^-	24-11-1	24-11-2
^{32}P	14.28 (2) h	β^-	32-15-1	32-15-2
^{34m}Cl	32.23 (14) m	IT, EC	34m-17-1	34m-17-2
^{35}S	87.4 (2) d	β^-	35-16-1	
^{38}K	7.613 (11) m	EC	38-19-1	38-19-2
^{42}K	12.360 (4) h	β^-	42-19-1	42-19-2
^{43}K	22.2 (3) h	β^-	43-19-1	43-19-2
^{44}Sc	3.927 (8) h	EC	44-21-1	44-21-2
^{44m}Sc	2.442 (4) d	IT, EC	44m-21-1	44m-21-2
^{45}Ti	3.08 (1) h	EC	45-22-1	45-22-2
^{48}V	15.974 (3) d	EC	48-23-1	48-23-2
^{49}Cr	42.1 (2) m	EC	49-24-1	49-24-2
^{51}Cr	27.697 (4) d	EC	51-24-1	51-24-2
^{52m}Mn	21.2 (4) m	IT, EC	52m-25-1	52m-25-2
^{52}Fe	8.26 (2) h	EC	52-26-1	52-26-2
^{55}Fe	991 (9) d	EC	55-26-1	
^{55}Co	15.54 (4) h	EC	55-27-1	55-27-2
^{56}Co	77.9 (13) d	EC	56-27-1 56-27-1a	56-27-2 56-27-2a
^{57}Co	271.76 (7) d	EC	57-27-1	57-27-2
^{57}Ni	36.08 (9) h	EC	57-28-1	57-28-2
^{58}Co	70.91 (2) d	EC	58-27-1	58-27-2
^{59}Fe	44.50 (1) d	β^-	59-26-1	59-26-2
^{60}Co	5.2712 (11) y	β^-	60-27-1	60-27-2
^{61}Cu	3.408 (10) h	EC	61-29-1	61-29-2
^{62}Cu	9.74 (2) m	EC, β^+	62-29-1	62-29-2
^{64}Cu	17.703 (2) h	β^-, EC, β^+	64-29-1	64-29-2
^{65}Zn	243.9 (2) d	EC, β^+	65-30-1	65-30-2
^{67}Cu	61.79 (9) h	β^-	67-29-1	67-29-2
^{67}Ga	78.255 (23) h	EC	67-31-1	67-31-2
^{68}Ga	68.0 (2) m	EC, β^+	68-31-1	68-31-2
^{69m}Zn	13.9 (2) h	IT, β^-	69m-30-1	69m-30-2
^{69}Ge	39.05 (10) h	EC, β^+	69-32-1	69-32-2
^{75}Se	119.77 (9) d	EC	75-34-1	75-34-2

Table 2. (cont.)

Nuclide	Half-life	Decay	Ge, Si	NaJ(Tl)
1	2	3	4	5
^{82}Rb	1.25 (3) m	EC, β^+	82-37-1	82-37-2
^{85}Sr	64.85 (1) h	EC	85-38-1	85-38-2
^{86}Rb	18.63 (2) d	β^-, β^+	86-37-1	86-37-2
^{87m}Sr	2.82 (1) h	IT, EC	87m-38-1	87m-38-2
^{89}Sr	50.62 (6) d	β^-	89-38-1	89-38-2
^{90}Y	64.26 (7) h	IT, β^-	90-39-1	90-39-2
^{91}Y	58.51 (6) h	β^-	91-39-1	91-39-2
^{97}Ru	2.88 (4) d	EC	97-44-1	97-44-2
^{99}Mo+	66.02 (2) h	β^-, IT	99+-42-1	99+-42-2
^{99m}Tc	6.012 (4) h	IT	99m-43-1	99m-43-2
^{101m}Rh	4.34 (1) d	IT, EC	101m-45-1	101m-45-2
^{111}In	2.803 (3) d	EC	111-49-1	111-49-2
^{113}In	99.48 (2) m	IT	113m-49-1	113m-49-2
^{118}Sb	3.6 (1) m	β^+, EC	118-51-1	118-51-2
^{123}I	13.25 (3) h	EC	123-53-1	123-53-2
^{125}I	59.2 (1) d	EC	125-53-1	125-53-2
^{127}Xe	36.4 (1) d	EC	127-54-1	127-54-2
^{128}Cs	3.62 (2) m	β^+, EC	128-55-1	128-55-2
^{131}I	8.021 (2) h	β^-	131-53-1	131-53-2
^{133}Xe	5.247 (2) d	β^-	133-54-1	133-54-2
^{134}La	6.45 (16) m	β^+, EC	134-57-1	134-57-2
^{137m}Ba	2.554 (2) m	IT	137m-56-1	137m-56-2
^{140}La	40.29 (1) h	β^-	140-57-1	140-57-2
^{143}Pr	13.57 (2) d	β^-	143-59-1	143-59-2
^{167}Tm	9.25 (2) d	EC	167-69-1	167-69-2
^{169}Er	9.40 (2) d	β^-	169-68-1	169-68-2
^{169}Yb	32.02 (2) d	EC	169-70-1	169-70-2
^{178}Ta	2.45 (5) h	EC	178-73-1	178-73-2
^{198}Au	2.695 (1) d	β^-	198-79-1	198-79-2
^{201}Tl	72.93 (2) h	EC	201-81-1	201-81-2
^{202}Tl	12.24 (4) d	EC	202-81-1	202-81-2
^{203}Pb	52.0 (2) h	EC	203-82-1	203-82-2
^{211}At	7.23 (2) h	α	211-85-1	211-85-2

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