

**Nuclear Wallet Cards  
for Radioactive Nuclides**

March 2004

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for

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## **Data Resource Centers**

### **Brookhaven National Laboratory**

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### **Triangle Universities**

**Nuclear Laboratory**  
Nuclear Data Evaluation Project  
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Durham, NC 27708-0308  
Web: [www.tunl.duke.edu/NuclData/](http://www.tunl.duke.edu/NuclData/)

## Introduction

This quick reference has been prepared as a resource for field personnel, *e.g.*, for those in the area of Homeland Security.

Table I is based on the author's *Nuclear Wallet Cards*, last produced in January 2000 and updated using data given in *Evaluated Nuclear Structure Data File* [1]. The data for Table II are taken from reference [1].

### Explanation of Table I

All naturally-occurring radioactive nuclides and others with half-life ( $T_{1/2}$ )  $\geq 1$  h and  $Z \leq 100$  are included. The shorter  $T_{1/2}$  given are those seen as decay products of long-lived radioactive chains occurring in nature, see p. 31.

**Nuclide:** Nuclides are listed in the order of increasing atomic number ( $Z$ ), and are sub-ordered by increasing mass number ( $A$ ).

Long-lived excited states are denoted by the symbol "m" after the mass number. Radionuclides which occur in nature [2] and some of the other well known radioactive nuclides appear with **bold**  $A$ -number (see also p.32-33).

**Half-Life,  $T_{1/2}$**  is given followed by its units (s: second, m: minute, h: hour, d: day, y: year).

**Major Radiations:** Only  $\alpha$ ,  $\epsilon$ ,  $\beta^-$ ,  $\gamma$ , and SF(spontaneous fission) are indicated. Electron capture without significant X-/ $\gamma$ -ray emissions are given as  $\epsilon$ .

**Major Gamma Radiation** energies in decay, of the parent nuclide are given. The maximum of three X/ $\gamma$  rays, with intensity  $>2\%$ , are given. The 2<sup>nd</sup> transition is omitted if it is

### **Explanation of Table I (cont.)**

<1% of first transition. The third transition is omitted if it is <10% of the 2<sup>nd</sup> transition. The X/ $\gamma$  rays given belong to the daughter nuclide alone. *In case of the daughter nuclide being radioactive one could observe X/ $\gamma$  rays from several nuclides down the decay chain.* A <sup>235</sup>U source, for example, in equilibrium with its daughters (as it occurs in nature) will show activity from several of nuclides in the decay chain. See page 31 for naturally-occurring decay chains.

### **Explanation of Table II**

Table II lists the X-/ $\gamma$ -ray energies with their parent associations. The X-/ $\gamma$ -ray energies >100 keV and <3000 keV are listed. Only those nuclides for which X-/ $\gamma$ -ray intensities are >5% are included. *Only immediate parents are included.*

### **Acknowledgements**

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### **References**

1. *Evaluated Nuclear Structure Data File*—Maintained by the National Nuclear Data Center, Brookhaven National Laboratory.
2. *Chart of the Nuclides* 16th Edition, 2002. Knolls Atomic Power Laboratory, Lockheed Martin Corporation.



**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>
<b>1 H 3</b>	12.32 y	$\beta^-$	
<b>4 Be 7</b>	53.22 d	$\epsilon$	
	10 $1.51 \times 10^6$ y	$\beta^-$	
<b>6 C 14</b>	5700 y	$\beta^-$	
<b>9 F 18</b>	1.829 h	$\gamma$	511
<b>11 Na 22</b>	2.602 y	$\gamma$	511, 1275
	24 14.96 h	$\beta^-, \gamma$	1369, 2754
<b>12 Mg 28</b>	20.92 h	$\beta^-, \gamma$	1342, 941, 401
<b>13 Al 26</b>	$7.17 \times 10^5$ y	$\gamma$	511, 1809
<b>14 Si 31</b>	2.622 h	$\beta^-$	
	32 132 y	$\beta^-$	
<b>15 P 32</b>	14.26 d	$\beta^-$	
	33 25.34 d	$\beta^-$	
<b>16 S 35</b>	87.51 d	$\beta^-$	
	38 2.838 h	$\beta^-, \gamma$	1942, 1746
<b>17 Cl 36</b>	$3.01 \times 10^5$ y	$\beta^-$	
<b>18 Ar 37</b>	35.04 d	$\epsilon$	
	39 269 y	$\beta^-$	
	41 1.827 h	$\beta^-, \gamma$	1294
	42 32.9 y	$\beta^-$	
<b>19 K 40</b>	$1.265 \times 10^9$ y	$\beta^-, \gamma$	1461
	42 12.36 h	$\beta^-, \gamma$	1525
	43 22.3 h	$\beta^-, \gamma$	373, 617, 397
<b>20 Ca 41</b>	$1.02 \times 10^5$ y	$\epsilon$	
	45 162.6 d	$\beta^-$	
	47 4.536 d	$\beta^-, \gamma$	1297, 489, 808
<b>21 Sc 43</b>	3.891 h	$\gamma$	511, 373
	44 3.97 h	$\gamma$	511, 1157
	44m 2.442 d	$\gamma$	271
	46 83.79 d	$\beta^-, \gamma$	1121, 889
	47 3.349 d	$\beta^-, \gamma$	159
	48 1.82 d	$\beta^-, \gamma$	984, 1312, 1038
<b>22 Ti 44</b>	60 y	$\gamma$	78, 68
	45 3.08 h	$\gamma$	511
<b>23 V 48</b>	15.97 d	$\gamma$	511, 984, 1312
	49 330 d	$\epsilon$	
	50 $1.4 \times 10^{17}$ y	$\gamma$	1554, 783
<b>24 Cr 48</b>	21.56 h	$\gamma$	308, 112
	51 27.7 d	$\gamma$	320
<b>25 Mn 52</b>	5.591 d	$\gamma$	1434, 936, 744
	53 $3.74 \times 10^6$ y	$\epsilon$	
	54 312.1 d	$\gamma$	835
	56 2.579 h	$\beta^-, \gamma$	847, 1811, 2113
<b>26 Fe 52</b>	8.275 h	$\gamma$	511, 169
	55 2.737 y	$\epsilon$	
	59 44.5 d	$\beta^-, \gamma$	1099, 1292
	60 $1.5 \times 10^6$ y	$\beta^-, \gamma$	59

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>	
<b>27 Co</b>	55	17.53 h	$\gamma$	511, 931, 477
	<b>56</b>	77.23 d	$\gamma$	847, 1238, 511
	<b>57</b>	271.7 d	$\gamma$	122, 136
	<b>58</b>	70.86 d	$\gamma$	811, 511
	58m	9.04 h	$\gamma$	
	<b>60</b>	5.271 y	$\beta^{-}, \gamma$	1332, 1173
	61	1.65 h	$\beta^{-}, \gamma$	67, 909
<b>28 Ni</b>	56	6.075 d	$\gamma$	158, 812, 750
	57	1.483 d	$\gamma$	511, 1378, 127
	59	$7.6 \times 10^4$ y	$\epsilon$	
	63	100.1 y	$\beta^{-}$	
	65	2.517 h	$\beta^{-}, \gamma$	1482, 1116, 366
	66	2.275 d	$\beta^{-}$	
<b>29 Cu</b>	61	3.333 h	$\gamma$	511, 283, 656
	<b>64</b>	12.7 h	$\gamma$	511
	<b>67</b>	2.576 d	$\beta^{-}, \gamma$	185, 93, 91
<b>30 Zn</b>	62	9.186 h	$\gamma$	597, 511, 548
	<b>65</b>	244.1 d	$\gamma$	1116, 511
	69m	13.76 h	$\gamma$	439
	71m	3.96 h	$\beta^{-}, \gamma$	386, 487, 620
	72	1.938 d	$\beta^{-}, \gamma$	145, 191, 103
<b>31 Ga</b>	<b>66</b>	9.49 h	$\gamma$	511, 1039, 2752
	<b>67</b>	3.261 d	$\gamma$	93, 185, 300
	<b>68</b>	1.127 h	$\gamma$	511, 1077
	72	14.1 h	$\beta^{-}, \gamma$	834, 2202, 630
	73	4.86 h	$\beta^{-}, \gamma$	297, 326, 739
<b>32 Ge</b>	66	2.26 h	$\gamma$	511, 382, 109
	<b>68</b>	270.8 d	$\epsilon$	
	69	1.627 d	$\gamma$	511, 1107, 574
	71	11.43 d	$\epsilon$	
	75	1.38 h	$\beta^{-}, \gamma$	265
	77	11.3 h	$\beta^{-}, \gamma$	264, 211, 215
	78	1.467 h	$\beta^{-}, \gamma$	277, 294
<b>33 As</b>	71	2.72 d	$\gamma$	175, 511
	72	1.083 d	$\gamma$	511, 834
	73	80.3 d	$\gamma$	53
	74	17.77 d	$\gamma$	596, 511, 635
	76	1.078 d	$\beta^{-}, \gamma$	559, 657, 1216
	77	1.618 d	$\beta^{-}$	
	78	1.512 h	$\beta^{-}, \gamma$	614, 695, 1309
	<b>34 Se</b>	72	8.4 d	$\epsilon$
73		7.15 h	$\gamma$	511, 361, 67
<b>75</b>		119.8 d	$\gamma$	265, 136, 280
79		$2.95 \times 10^5$ y	$\beta^{-}$	
<b>35 Br</b>	75	1.612 h	$\gamma$	511, 286
	76	16.2 h	$\gamma$	511, 559, 657
	77	2.377 d	$\gamma$	239, 521, 297
	80m	4.42 h	$\gamma$	
	82	1.47 d	$\beta^{-}, \gamma$	777, 554, 619
	83	2.4 h	$\beta^{-}$	

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$		
<b>36 Kr</b>	76	14.8 h	$\gamma$	316, 270, 406	
	77	1.24 h	$\gamma$	511, 130, 147	
	79	1.46 d	$\gamma$	511, 261, 398	
	81	$2.29 \times 10^5$ y	$\epsilon$		
	83m	1.83 h	$\gamma$		
	<b>85</b>	10.77 y	$\beta^-$		
	85m	4.48 h	$\beta^-$ , $\gamma$	151, 305	
	87	1.272 h	$\beta^-$ , $\gamma$	403, 2555, 845	
	88	2.84 h	$\beta^-$ , $\gamma$	2392, 196, 2196	
	<b>37 Rb</b>	<b>81</b>	4.576 h	$\gamma$	190, 511, 446
82m		6.472 h	$\gamma$	777, 554, 511	
83		86.2 d	$\gamma$	520, 530, 553	
84		32.77 d	$\gamma$	882, 511	
86		18.64 d	$\beta^-$ , $\gamma$	1077	
<b>87</b>		$4.81 \times 10^{10}$ y	$\beta^-$		
<b>38 Sr</b>		80	1.772 h	$\gamma$	589, 511, 175
	<b>82</b>	25.55 d	$\epsilon$		
	83	1.35 d	$\gamma$	511, 763, 382	
	<b>85</b>	64.84 d	$\gamma$	514	
	85m	1.127 h	$\gamma$	232, 151	
	<b>87m</b>	2.815 h	$\gamma$	389	
	<b>89</b>	50.53 d	$\beta^-$		
	<b>90</b>	28.79 y	$\beta^-$		
	91	9.63 h	$\beta^-$ , $\gamma$	1024, 750, 653	
	92	2.66 h	$\beta^-$ , $\gamma$	1384, 953, 430	
	<b>39 Y</b>	85	2.68 h	$\gamma$	511, 232, 504
		85m	4.86 h	$\gamma$	511, 232, 2124
86		14.74 h	$\gamma$	1077, 511, 628	
87		3.325 d	$\gamma$	485, 389	
87m		13.37 h	$\gamma$	381	
<b>88</b>		106.6 d	$\gamma$	1836, 898	
<b>90</b>		2.667 d	$\beta^-$		
90m		3.19 h	$\gamma$	203, 480	
91		58.51 d	$\beta^-$		
92		3.54 h	$\beta^-$ , $\gamma$	934, 1405, 561	
93		10.18 h	$\beta^-$ , $\gamma$	267, 947	
<b>40 Zr</b>		86	16.5 h	$\gamma$	243, 612
	87	1.68 h	$\gamma$	511, 380, 1227	
	88	83.4 d	$\gamma$	393	
	89	3.267 d	$\gamma$	909, 511	
	93	$1.53 \times 10^6$ y	$\beta^-$		
	95	64.03 d	$\beta^-$ , $\gamma$	757, 724	
	97	16.74 h	$\beta^-$ , $\gamma$	743, 508, 1148	
<b>41 Nb</b>	89	2.03 h	$\gamma$	511, 1627, 1833	
	89m	1.1 h	$\gamma$	511, 588, 507	
	90	14.6 h	$\gamma$	511, 1129, 2319	
	91	$6.8 \times 10^2$ y	$\epsilon$		
	91m	60.86 d	$\gamma$	1205	
	92	$3.47 \times 10^7$ y	$\gamma$	561, 934	
	92m	10.15 d	$\gamma$	934	
	<b>93m</b>	16.13 y	$\gamma$		

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>		
<b>41 Nb</b>	<b>94</b>	$2.03 \times 10^4$ y	$\beta^-$ , $\gamma$	871, 703	
	<b>95</b>	34.99 d	$\beta^-$ , $\gamma$	766	
	95m	3.61 d	$\gamma$	236, 204	
	96	23.35 h	$\beta^-$ , $\gamma$	778, 569, 1091	
	97	1.202 h	$\beta^-$ , $\gamma$	658	
<b>42 Mo</b>	90	5.56 h	$\gamma$	257, 122, 511	
	93	$4.0 \times 10^3$ y	$\epsilon$		
	93m	6.85 h	$\gamma$	685, 1477, 263	
	<b>99</b>	2.747 d	$\beta^-$ , $\gamma$	739, 181, 141	
	<b>43 Tc</b>	93	2.75 h	$\gamma$	1363, 1520, 511
94		4.883 h	$\gamma$	871, 703, 850	
95		20 h	$\gamma$	766, 1074	
95m		61 d	$\gamma$	204, 582, 835	
96		4.28 d	$\gamma$	778, 850, 813	
97		$4.21 \times 10^6$ y	$\epsilon$		
97m		91.4 d	$\gamma$		
98		$4.2 \times 10^6$ y	$\beta^-$ , $\gamma$	745, 652	
<b>99</b>		$2.111 \times 10^5$ y	$\beta^-$		
99m		6.015 h	$\gamma$	141	
<b>44 Ru</b>		95	1.643 h	$\gamma$	336, 511, 1097
	97	2.791 d	$\gamma$	216, 324	
	<b>103</b>	39.26 d	$\beta^-$ , $\gamma$	497, 610	
	105	4.44 h	$\beta^-$ , $\gamma$	724, 469, 676	
	<b>106</b>	1.023 y	$\beta^-$		
	<b>45 Rh</b>	99	16.1 d	$\gamma$	528, 353, 90
99m		4.7 h	$\gamma$	341, 511, 618	
100		20.8 h	$\gamma$	540, 2376, 823	
101		3.3 y	$\gamma$	198, 127, 325	
101m		4.34 d	$\gamma$	307, 545	
102		207 d	$\gamma$	475, 511, 628	
102m		$\approx 2.9$ y	$\gamma$	475, 631, 697	
105		1.473 d	$\beta^-$ , $\gamma$	319, 306	
106m		2.183 h	$\beta^-$ , $\gamma$	512, 1047, 717	
<b>46 Pd</b>		100	3.63 d	$\gamma$	84, 75, 126
		101	8.47 h	$\gamma$	296, 590, 511
	<b>103</b>	16.99 d	$\epsilon$		
	107	$6.5 \times 10^6$ y	$\beta^-$		
	109	13.7 h	$\beta^-$ , $\gamma$	88	
	111m	5.5 h	$\gamma$	172, 70	
	112	21.03 h	$\beta^-$		
	<b>47 Ag</b>	103	1.095 h	$\gamma$	511, 119, 148
104		1.153 h	$\gamma$	556, 768, 511	
105		41.29 d	$\gamma$	345, 280, 645	
106m		8.28 d	$\gamma$	512, 1046, 717	
108m		418 y	$\gamma$	723, 434, 614	
110m		249.8 d	$\beta^-$ , $\gamma$	658, 885, 937	
<b>111</b>		7.45 d	$\beta^-$ , $\gamma$	342	
112		3.13 h	$\beta^-$ , $\gamma$	617, 1388, 607	
113		5.37 h	$\beta^-$ , $\gamma$	299	
<b>48 Cd</b>		107	6.5 h	$\gamma$	93

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$
<b>48 Cd 109</b>	1.263 y	$\gamma$	88
<b>113</b>	$7.7 \times 10^{15}$ y	$\beta^-$	
113m	14.1 y	$\beta^-$	
115	2.227 d	$\beta^-$ , $\gamma$	336, 528, 492
115m	44.56 d	$\beta^-$ , $\gamma$	934
117	2.49 h	$\beta^-$ , $\gamma$	273, 1303, 344
117m	3.36 h	$\beta^-$ , $\gamma$	1997, 1066, 564
<b>49 In 109</b>	4.2 h	$\gamma$	203, 511, 623
110	4.9 h	$\gamma$	658, 885, 937
110m	1.152 h	$\gamma$	511, 658
<b>111</b>	2.805 d	$\gamma$	245, 171
113m	1.658 h	$\gamma$	392
114m	49.51 d	$\gamma$	190, 558, 725
<b>115</b>	$4.41 \times 10^{14}$ y	$\beta^-$	
115m	4.486 h	$\gamma$	336
117m	1.937 h	$\beta^-$ , $\gamma$	315, 159
<b>50 Sn 110</b>	4.11 h	$\gamma$	283
<b>113</b>	115.1 d	$\gamma$	392, 255
117m	13.76 d	$\gamma$	159, 156
119m	293.1 d	$\gamma$	
121	1.126 d	$\beta^-$	
121m	55 y	$\gamma$	
123	129.2 d	$\beta^-$	
125	9.64 d	$\beta^-$ , $\gamma$	1067, 1089, 822
126	$2.30 \times 10^5$ y	$\beta^-$ , $\gamma$	88, 64, 87
127	2.1 h	$\beta^-$ , $\gamma$	1114, 1096, 823
<b>51 Sb 116m</b>	1.005 h	$\gamma$	1294, 973, 511
117	2.8 h	$\gamma$	159, 511
118m	5 h	$\gamma$	1230, 254, 1051
119	1.591 d	$\epsilon$	
120m	5.76 d	$\gamma$	1172, 1023, 197
122	2.724 d	$\beta^-$ , $\gamma$	564, 693
124	60.2 d	$\beta^-$ , $\gamma$	603, 1691, 723
<b>125</b>	2.759 y	$\beta^-$ , $\gamma$	428, 601, 636
126	12.35 d	$\beta^-$ , $\gamma$	666, 695, 415
127	3.85 d	$\beta^-$ , $\gamma$	686, 473, 784
128	9.01 h	$\beta^-$ , $\gamma$	743, 754, 314
129	4.4 h	$\beta^-$ , $\gamma$	813, 915, 545
<b>52 Te 116</b>	2.49 h	$\gamma$	94, 629
117	1.033 h	$\gamma$	720, 511, 1716
118	6 d	$\epsilon$	
119	16.05 h	$\gamma$	644, 700, 511
119m	4.7 d	$\gamma$	1213, 154, 271
121	19.16 d	$\gamma$	573, 508
121m	154 d	$\gamma$	212, 1102
<b>123</b>	$> 6 \times 10^{14}$ y	$\epsilon$	
<b>123m</b>	119.3 d	$\gamma$	159
125m	57.4 d	$\gamma$	
127	9.35 h	$\beta^-$	
127m	109 d	$\gamma$	
129	1.16 h	$\beta^-$ , $\gamma$	460

**Table I – Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>
<b>52 Te</b>	129m	33.6 d	$\gamma$ 696
	131m	1.25 d	$\beta^{-}, \gamma$ 774, 852, 794
	132	3.204 d	$\beta^{-}, \gamma$ 228
<b>53 I</b>	120	1.36 h	$\gamma$ 511, 560, 1523
	121	2.12 h	$\gamma$ 212, 511, 532
	<b>123</b>	13.27 h	$\gamma$ 159
	<b>124</b>	4.176 d	$\gamma$ 603, 511, 1691
	<b>125</b>	59.4 d	$\epsilon$
	126	12.93 d	$\gamma$ 389, 666, 754
	<b>129</b>	$1.57 \times 10^7$ y	$\beta^{-}$
	130	12.36 h	$\beta^{-}, \gamma$ 536, 669, 740
	<b>131</b>	8.021 d	$\beta^{-}, \gamma$ 364, 637, 284
	132	2.295 h	$\beta^{-}, \gamma$ 668, 773, 955
	132m	1.387 h	$\gamma$ 600, 773, 668
	133	20.8 h	$\beta^{-}, \gamma$ 530, 875, 1298
	135	6.57 h	$\beta^{-}, \gamma$ 1260, 1132, 1678
<b>54 Xe</b>	122	20.1 h	$\gamma$ 350, 149
	<b>123</b>	2.08 h	$\gamma$ 149, 511, 178
	<b>125</b>	16.9 h	$\gamma$ 188, 243, 55
	<b>127</b>	36.4 d	$\gamma$ 203, 172, 375
	129m	8.88 d	$\gamma$ 197
	131m	11.93 d	$\gamma$
	<b>133</b>	5.243 d	$\beta^{-}, \gamma$ 81
	133m	2.19 d	$\gamma$ 233
	135	9.14 h	$\beta^{-}, \gamma$ 250, 608
	<b>55 Cs</b>	127	6.25 h
129		1.336 d	$\gamma$ 372, 411, 549
131		9.689 d	$\epsilon$
132		6.479 d	$\gamma$ 668
<b>134</b>		2.066 y	$\beta^{-}, \gamma$ 605, 796, 569
134m		2.903 h	$\gamma$ 128
135		$2.3 \times 10^6$ y	$\beta^{-}$
136		13.16 d	$\beta^{-}, \gamma$ 819, 1048, 341
<b>137</b>		30.07 y	$\beta^{-}, \gamma$ 662
<b>56 Ba</b>		126	1.667 h
	128	2.43 d	$\gamma$ 273
	129	2.23 h	$\gamma$ 511, 214, 221
	129m	2.16 h	$\gamma$ 511, 214, 221
	131	11.5 d	$\gamma$ 496, 124, 216
	<b>133</b>	10.54 y	$\gamma$ 356, 81, 303
	<b>133m</b>	1.621 d	$\gamma$ 276
	135m	1.196 d	$\gamma$ 268
	139	1.384 h	$\beta^{-}, \gamma$ 166
	140	12.75 d	$\beta^{-}, \gamma$ 537, 163, 305
	<b>57 La</b>	132	4.8 h
133		3.912 h	$\gamma$ 511
135		19.5 h	$\epsilon$
137		$6 \times 10^4$ y	$\epsilon$
<b>138</b>		$1.02 \times 10^{11}$ y	$\gamma$ 1436, 789
140		1.678 d	$\beta^{-}, \gamma$ 1596, 487, 816
141		3.92 h	$\beta^{-}$

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>
<b>57 La</b> 142	1.518 h	$\beta^{-}, \gamma$	641, 2398, 2543
<b>58 Ce</b>	132	$\gamma$	182, 155, 217
	133	$\gamma$	511, 97, 77
	133m	$\gamma$	477, 510, 58
	134	$\epsilon$	
	135	$\gamma$	266, 300, 607
	137	$\epsilon$	
	137m	$\gamma$	254
	<b>139</b>	$\gamma$	166
	<b>141</b>	$\beta^{-}, \gamma$	145
	143	$\beta^{-}, \gamma$	293, 57, 665
<b>144</b>	$\beta^{-}, \gamma$	134	
<b>59 Pr</b>	137	$\gamma$	511
	138m	$\gamma$	1038, 789, 303
	139	$\gamma$	511
	142	$\beta^{-}, \gamma$	1576
	143	$\beta^{-}$	
	145	$\beta^{-}$	
<b>60 Nd</b>	<b>138</b>	$\gamma$	326
	139m	$\gamma$	114, 738, 708
	<b>140</b>	$\epsilon$	
	141	$\gamma$	511
	<b>144</b>	$2.29 \times 10^{15}$ y $\alpha$	
	147	$\beta^{-}, \gamma$	91, 531
	149	$\beta^{-}, \gamma$	211, 114, 270
<b>61 Pm</b>	143	$\gamma$	742
	144	$\gamma$	696, 618, 477
	145	$\epsilon$	
	146	$\gamma$	454, 747, 736
	<b>147</b>	$\beta^{-}$	
	148	$\beta^{-}, \gamma$	1465, 550, 915
	148m	$\beta^{-}, \gamma$	550, 630, 726
	149	$\beta^{-}, \gamma$	286
	150	$\beta^{-}, \gamma$	334, 1325, 1166
	151	$\beta^{-}, \gamma$	340, 168, 275
	<b>62 Sm</b>	142	$\gamma$
145		$\gamma$	61
146		$10.3 \times 10^7$ y $\alpha$	
<b>147</b>		$1.06 \times 10^{11}$ y $\alpha$	
<b>148</b>		$7 \times 10^{15}$ y $\alpha$	
151		$\beta^{-}$	
<b>153</b>		$\beta^{-}, \gamma$	103, 70
156		$\beta^{-}, \gamma$	88, 204, 166
<b>63 Eu</b>		145	$\gamma$
	146	$\gamma$	747, 634, 633
	147	$\gamma$	197, 121, 678
	148	$\gamma$	550, 630, 611
	149	$\gamma$	328, 277
	150	$\gamma$	334, 439, 584
	150m	$\beta^{-}, \gamma$	334, 406

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$	
<b>63 Eu</b>	<b>152</b>	13.52 y	$\gamma$	122, 344, 1408
	152m	9.312 h	$\beta^{-}, \gamma$	842, 963, 122
	152m	1.6 h	$\gamma$	90
	<b>154</b>	8.593 y	$\beta^{-}, \gamma$	123, 1274, 723
	<b>155</b>	4.761 y	$\beta^{-}, \gamma$	87, 105
	156	15.19 d	$\beta^{-}, \gamma$	812, 89, 1231
	157	15.18 h	$\beta^{-}, \gamma$	64, 411, 371
<b>64 Gd</b>	146	48.27 d	$\gamma$	155, 115, 116
	147	1.586 d	$\gamma$	229, 396, 929
	148	74.6 y	$\alpha$	
	149	9.28 d	$\gamma$	150, 299, 347
	150	$1.79 \times 10^6$ y	$\alpha$	
	151	124 d	$\gamma$	154, 243, 175
	<b>152</b>	$1.08 \times 10^{14}$ y	$\alpha$	
	153	240.4 d	$\gamma$	97, 103, 70
	159	18.48 h	$\beta^{-}, \gamma$	364, 50, 58
	<b>65 Tb</b>	147	1.7 h	$\gamma$
148		1 h	$\gamma$	511, 784, 489
<b>149</b>		4.118 h	$\gamma$	352, 165, 389
150		3.48 h	$\gamma$	638, 511, 496
151		17.61 h	$\gamma$	287, 252, 108
<b>152</b>		17.5 h	$\gamma$	344, 511, 586
153		2.34 d	$\gamma$	212, 110, 102
154		21.5 h	$\gamma$	123, 1274, 2187
154m		9.4 h	$\gamma$	123, 248, 540
154m		22.7 h	$\gamma$	123, 1274, 2187
155		5.32 d	$\gamma$	87, 105, 180
156		5.35 d	$\gamma$	534, 199, 1222
156m		1.017 d	$\gamma$	
156m		5.3 h	$\gamma$	
157		71 y	$\epsilon$	
158		180 y	$\gamma$	99
160		72.3 d	$\beta^{-}, \gamma$	879, 299, 966
161	6.906 d	$\beta^{-}, \gamma$	75, 52	
<b>66 Dy</b>	152	2.38 h	$\gamma$	257, 50
	153	6.4 h	$\gamma$	50, 81, 214
	154	$3.0 \times 10^6$ y	$\alpha$	
	155	9.9 h	$\gamma$	227, 50, 185
	157	8.14 h	$\gamma$	326, 50
	159	144.4 d	$\gamma$	50, 58
	165	2.334 h	$\beta^{-}, \gamma$	95
	166	3.4 d	$\beta^{-}, \gamma$	82, 54
	<b>67 Ho</b>	160m	5.02 h	$\gamma$
161		2.48 h	$\gamma$	52, 103
162m		1.117 h	$\gamma$	185, 1220, 283
163		4570 y	$\epsilon$	
<b>166</b>		1.118 d	$\beta^{-}, \gamma$	81, 56
<b>166m</b>		$1.20 \times 10^3$ y	$\beta^{-}, \gamma$	184, 810, 712
167		3.1 h	$\beta^{-}, \gamma$	346, 321, 238
<b>68 Er</b>	158	2.29 h	$\gamma$	54, 72, 387
	160	1.191 d	$\gamma$	54



**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$		
<b>68 Er</b>	161	3.21 h	$\gamma$	827, 54, 211	
	163	1.25 h	$\gamma$	54	
	165	10.36 h	$\gamma$	54	
	<b>169</b>	9.4 d	$\beta^-$		
	171	7.516 h	$\beta^-$ , $\gamma$	308, 296, 51	
	172	2.054 d	$\beta^-$ , $\gamma$	610, 407, 51	
<b>69 Tm</b>	163	1.81 h	$\gamma$	56, 104, 69	
	165	1.252 d	$\gamma$	243, 56, 297	
	166	7.7 h	$\gamma$	56, 779, 2052	
	167	9.25 d	$\gamma$	208, 56, 57	
	168	93.1 d	$\gamma$	198, 816, 448	
	<b>170</b>	128.6 d	$\beta^-$ , $\gamma$	84	
	171	1.92 y	$\beta^-$		
	172	2.65 d	$\beta^-$ , $\gamma$	79, 1094, 1387	
	173	8.24 h	$\beta^-$ , $\gamma$	399, 461, 52	
	<b>70 Yb</b>	164	1.263 h	$\gamma$	51, 57
166		2.362 d	$\gamma$	51, 82, 57	
<b>169</b>		32.03 d	$\gamma$	51, 63, 57	
175		4.185 d	$\beta^-$ , $\gamma$	396, 283	
177		1.911 h	$\beta^-$ , $\gamma$	150, 1080, 54	
178		1.233 h	$\beta^-$		
<b>71 Lu</b>	169	1.419 d	$\gamma$	52, 51, 59	
	170	2.012 d	$\gamma$	52, 51, 59	
	171	8.24 d	$\gamma$	52, 740, 51	
	172	6.7 d	$\gamma$	1094, 52, 51	
	173	1.37 y	$\gamma$	52, 51, 59	
	174	3.31 y	$\gamma$	52, 51, 59	
	174m	142 d	$\gamma$	54, 53, 61	
	<b>176</b>	$4.00 \times 10^{10}$ y	$\beta^-$ , $\gamma$	307, 202, 56	
	176m	3.664 h	$\beta^-$ , $\gamma$	88	
	<b>177</b>	6.647 d	$\beta^-$ , $\gamma$	208, 113, 56	
	177m	160.4 d	$\beta^-$ , $\gamma$	56, 208, 228	
	179	4.59 h	$\beta^-$ , $\gamma$	214	
	<b>72 Hf</b>	170	16.01 h	$\gamma$	54, 53, 165
		171	12.1 h	$\epsilon$	
172		1.87 y	$\gamma$	54, 53, 61	
173		23.6 h	$\gamma$	124, 54, 297	
<b>174</b>		$2.0 \times 10^{15}$ y	$\alpha$		
175		70 d	$\gamma$	343, 54, 53	
178m		31 y	$\gamma$	426, 326, 574	
179m		25.05 d	$\gamma$	454, 56, 363	
180m		5.5 h	$\gamma$	332, 443, 215	
181		42.39 d	$\beta^-$ , $\gamma$	482, 133, 58	
182		$9 \times 10^6$ y	$\beta^-$ , $\gamma$	270, 58, 156	
182m		1.025 h	$\beta^-$ , $\gamma$	344, 224, 58	
183		1.067 h	$\beta^-$ , $\gamma$	784, 73, 459	
184		4.12 h	$\beta^-$ , $\gamma$	139, 345, 58	
<b>73 Ta</b>	173	3.14 h	$\gamma$	56, 55, 63	
	174	1.14 h	$\gamma$	206, 511, 56	
	175	10.5 h	$\gamma$	56, 55, 63	
	176	8.09 h	$\gamma$	56, 55, 1159	

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$
<b>73 Ta</b>	177	2.357 d	$\gamma$ 56, 55, 113
	178	2.36 h	$\gamma$ 426, 326, 213
	179	1.82 y	$\gamma$ 56, 55, 63
	<b>180</b>	8.152 h	$\gamma$ 56, 55, 63
	182	114.4 d	$\beta^{-}, \gamma$ 68, 1121, 1221
	183	5.1 d	$\beta^{-}, \gamma$ 59, 246, 58
	184	8.7 h	$\beta^{-}, \gamma$ 414, 253, 921
<b>74 W</b>	176	2.5 h	$\epsilon$
	177	2.2 h	$\gamma$ 58, 116, 56
	178	21.6 d	$\gamma$ 58, 56, 65
	181	121.2 d	$\gamma$ 58, 56, 65
	185	75.1 d	$\beta^{-}$
	187	23.72 h	$\beta^{-}, \gamma$ 686, 480, 61
	188	69.78 d	$\beta^{-}$
<b>75 Re</b>	181	19.9 h	$\gamma$ 59, 365, 58
	182	2.667 d	$\gamma$ 59, 58, 67
	182m	12.7 h	$\gamma$ 59, 68, 1121
	183	70 d	$\gamma$ 59, 58, 67
	184	38 d	$\gamma$ 59, 903, 792
	184m	169 d	$\gamma$ 61, 59, 60
	<b>186</b>	3.718 d	$\beta^{-}, \gamma$ 137, 59
	186m	$2.0 \times 10^5$ y	$\gamma$ 59
	<b>187</b>	$4.35 \times 10^{10}$ y	$\beta^{-}$
	<b>188</b>	17 h	$\beta^{-}, \gamma$ 155, 63
	189	1.013 d	$\beta^{-}, \gamma$ 217, 219, 245
	190m	3.2 h	$\beta^{-}, \gamma$ 187, 605, 558
<b>76 Os</b>	181	1.75 h	$\gamma$ 61, 239, 60
	182	22.1 h	$\gamma$ 510, 61, 180
	183	13 h	$\gamma$ 382, 61, 60
	183m	9.9 h	$\gamma$ 1102, 61, 1108
	185	93.6 d	$\gamma$ 646, 61, 60
	<b>186</b>	$2.0 \times 10^{15}$ y	$\alpha$
	189m	5.8 h	$\gamma$
	191	15.4 d	$\beta^{-}, \gamma$ 65, 129, 63
	191m	13.1 h	$\gamma$ 63, 61
	193	1.255 d	$\beta^{-}, \gamma$ 65, 139, 460
	194	6 y	$\beta^{-}$
	<b>77 Ir</b>	184	3.09 h
185		14.4 h	$\gamma$ 63, 254, 61
186		16.64 h	$\gamma$ 297, 63, 137
186m		1.9 h	$\gamma$ 63, 137, 61
187		10.5 h	$\gamma$ 63, 61, 71
188		1.729 d	$\gamma$ 63, 155, 61
189		13.2 d	$\gamma$ 63, 61, 71
190		11.78 d	$\gamma$ 187, 63, 605
190m		1.12 h	$\gamma$
190m		3.087 h	$\gamma$ 616, 502, 361
<b>192</b>		73.83 d	$\beta^{-}, \gamma$ 317, 468, 308
<b>192m</b>		241 y	$\gamma$
193m		10.53 d	$\gamma$
194		19.28 h	$\beta^{-}, \gamma$ 328, 294

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>		
<b>77 Ir</b>	194m	171 d	$\beta^{-}, \gamma$	483, 328, 600	
	195	2.5 h	$\beta^{-}, \gamma$	67, 65, 76	
	195m	3.8 h	$\beta^{-}, \gamma$	67, 65, 76	
	196m	1.4 h	$\beta^{-}, \gamma$	393, 521, 356	
<b>78 Pt</b>	185	1.182 h	$\epsilon$		
	186	2.08 h	$\gamma$	689, 65, 63	
	187	2.35 h	$\gamma$	65, 63, 74	
	188	10.2 d	$\gamma$	65, 63, 74	
	189	10.87 h	$\gamma$	65, 63, 74	
	<b>190</b>	$6.5 \times 10^{11}$ y	$\alpha$		
	191	2.802 d	$\gamma$	65, 63, 74	
	193	50 y	$\epsilon$		
	193m	4.33 d	$\gamma$	67, 65, 76	
	195m	4.02 d	$\gamma$	67, 65, 76	
	197	19.89 h	$\beta^{-}, \gamma$	77, 191	
	197m	1.59 h	$\gamma$	67, 65, 346	
	200	12.5 h	$\beta^{-}, \gamma$	76, 69, 67	
202	1.833 d	$\beta^{-}$			
<b>79 Au</b>	191	3.18 h	$\gamma$	67, 65, 76	
	192	4.94 h	$\gamma$	317, 67, 65	
	193	17.65 h	$\gamma$	67, 65, 76	
	194	1.584 d	$\gamma$	328, 67, 65	
	195	186.1 d	$\gamma$	67, 65, 76	
	196	6.183 d	$\gamma$	356, 67, 333	
	196m	9.6 h	$\gamma$	69, 148, 188	
	<b>198</b>	2.695 d	$\beta^{-}, \gamma$	412	
	198m	2.27 d	$\gamma$	215, 97, 180	
	199	3.139 d	$\beta^{-}, \gamma$	158, 71, 208	
	200m	18.7 h	$\beta^{-}, \gamma$	368, 498, 579	
	<b>80 Hg</b>	192	4.85 h	$\gamma$	69, 275, 67
		193	3.8 h	$\gamma$	69, 67, 78
193m		11.8 h	$\gamma$	69, 258, 67	
194		444 y	$\epsilon$		
195		9.9 h	$\gamma$	69, 67, 78	
195m		1.733 d	$\gamma$	262, 69, 67	
197		2.672 d	$\gamma$	69, 67, 78	
197m		23.8 h	$\gamma$	134, 71, 69	
<b>203</b>		46.61 d	$\beta^{-}, \gamma$	279, 73, 71	
<b>81 Tl</b>		195	1.16 h	$\gamma$	71, 69, 80
		196	1.84 h	$\gamma$	426, 71, 511
	196m	1.41 h	$\gamma$	426, 635, 695	
	197	2.84 h	$\gamma$	71, 69, 80	
	198	5.3 h	$\gamma$	412, 71, 69	
	198m	1.87 h	$\gamma$	412, 637, 587	
	199	7.42 h	$\gamma$	71, 69, 80	
	<b>200</b>	1.087 d	$\gamma$	368, 71, 1206	
	<b>201</b>	3.038 d	$\gamma$	71, 69, 80	
	<b>202</b>	12.23 d	$\gamma$	440, 71, 69	
	204	3.78 y	$\beta^{-}$		
	<b>206</b>	4.2 m	$\beta^{-}$		
	<b>207</b>	4.77 m	$\beta^{-}$		

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$
<b>81 Tl</b>	<b>208</b> 3.053 m	$\beta^-$ , $\gamma$	2615, 583, 511
	<b>210</b> 1.3 m	$\beta^-$ , $\gamma$	800, 296, 1316
<b>82 Pb</b>	198 2.4 h	$\gamma$	73, 290, 71
	199 1.5 h	$\gamma$	367, 73, 71
	200 21.5 h	$\gamma$	73, 148, 71
	201 9.33 h	$\gamma$	331, 73, 71
	202 $52.5 \times 10^3$ y	$\epsilon$	
	202m 3.53 h	$\gamma$	961, 422, 787
	203 2.161 d	$\gamma$	279, 73, 71
	204m 1.12 h	$\gamma$	899, 912, 375
	205 $1.53 \times 10^7$ y	$\epsilon$	
	209 3.253 h	$\beta^-$	
	<b>210</b> 22.2 y	$\beta^-$	
	<b>211</b> 36.1 m	$\beta^-$ , $\gamma$	405, 832
	<b>212</b> 10.64 h	$\beta^-$ , $\gamma$	239, 77, 75
	<b>214</b> 26.8 m	$\beta^-$ , $\gamma$	352, 295, 77
<b>83 Bi</b>	201 1.8 h	$\gamma$	75, 629, 73
	202 1.72 h	$\gamma$	961, 422, 657
	203 11.76 h	$\gamma$	75, 820, 73
	204 11.22 h	$\gamma$	899, 375, 984
	205 15.31 d	$\gamma$	75, 1764, 703
	206 6.243 d	$\gamma$	803, 881, 75
	<b>207</b> 32.9 y	$\gamma$	570, 1064, 75
	208 $3.68 \times 10^5$ y	$\gamma$	2610, 75, 73
	<b>210</b> 5.012 d	$\beta^-$	
	<b>210m</b> $3.04 \times 10^6$ y	$\alpha$ , $\gamma$	266, 305, 73
	<b>211</b> 2.14 m	$\alpha$ , $\gamma$	351
	<b>212</b> 1.009 h	$\beta^-$ , $\gamma$	727
	<b>214</b> 19.9 m	$\beta^-$ , $\gamma$	609, 1764, 1120
	<b>215</b> 7.6 m	$\beta^-$	
	<b>84 Po</b>	204 3.53 h	$\gamma$
205 1.66 h		$\gamma$	77, 872, 1001
206 8.8 d		$\gamma$	77, 1032, 75
207 5.8 h		$\gamma$	992, 77, 743
208 2.898 y		$\alpha$	
209 102 y		$\alpha$	
<b>210</b> 138.4 d		$\alpha$	
<b>211</b> 0.516 s		$\alpha$	
<b>212</b> 0.299 $\mu$ s		$\alpha$	
<b>214</b> 164.3 $\mu$ s		$\alpha$	
<b>215</b> 1.781 ms		$\alpha$	
<b>216</b> 0.145 s		$\alpha$	
<b>218</b> 3.1 m		$\alpha$	
<b>85 At</b>		207 1.8 h	$\gamma$
	208 1.63 h	$\gamma$	687, 660, 178
	209 5.41 h	$\gamma$	545, 782, 790
	210 8.1 h	$\gamma$	1181, 245, 1483
	<b>211</b> 7.214 h	$\gamma$	79, 77, 90
	<b>215</b> 0.1 ms	$\alpha$	
	<b>218</b> 1.5 s	$\alpha$	
	<b>219</b> 56 s	$\alpha$	

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$	
<b>86 Rn</b>	210	2.4 h	$\alpha, \gamma$	82
	211	14.6 h	$\gamma$	674, 1363, 82
	<b>219</b>	3.96 s	$\alpha, \gamma$	271, 402
	<b>220</b>	55.6 s	$\alpha$	
	<b>222</b>	3.823 d	$\alpha$	
224	1.783 h	$\beta^-$		
<b>87 Fr</b>	<b>223</b>	22 m	$\beta^-, \gamma$	50, 80, 235
<b>88 Ra</b>	<b>223</b>	11.43 d	$\alpha, \gamma$	84, 81, 269
	<b>224</b>	3.66 d	$\alpha, \gamma$	241
	225	14.9 d	$\beta^-$	
	<b>226</b>	1600 y	$\alpha, \gamma$	186
	<b>228</b>	5.75 y	$\beta^-$	
	230	1.55 h	$\beta^-, \gamma$	72, 63, 203
	<b>89 Ac</b>	224	2.78 h	$\gamma$
	<b>225</b>	10 d	$\alpha$	
	226	1.224 d	$\beta^-, \gamma$	230, 158, 253
	<b>227</b>	21.77 y	$\beta^-$	
	<b>228</b>	6.15 h	$\beta^-, \gamma$	911, 969, 338
	229	1.045 h	$\beta^-, \gamma$	165, 569, 93
<b>90 Th</b>	<b>227</b>	18.68 d	$\alpha, \gamma$	236, 50, 256
	<b>228</b>	1.912 y	$\alpha$	
	229	7340 y	$\alpha, \gamma$	88, 85, 100
	<b>230</b>	$7.538 \times 10^4$ y	$\alpha$	
	<b>231</b>	1.063 d	$\beta^-, \gamma$	84
	<b>232</b>	$1.405 \times 10^{10}$ y	$\alpha$	
	<b>234</b>	24.1 d	$\beta^-, \gamma$	63, 92, 93
<b>91 Pa</b>	228	22 h	$\gamma$	93, 90, 911
	229	1.5 d	$\gamma$	93, 90, 105
	230	17.4 d	$\gamma$	952, 93, 90
	<b>231</b>	$3.276 \times 10^4$ y	$\alpha, \gamma$	300, 303
	232	1.31 d	$\beta^-, \gamma$	969, 894, 150
	233	26.97 d	$\beta^-, \gamma$	312, 98, 95
	<b>234</b>	6.7 h	$\beta^-, \gamma$	98, 131, 946
	239	1.8 h	$\beta^-$	
<b>92 U</b>	230	20.8 d	$\alpha$	
	231	4.2 d	$\gamma$	96, 92, 108
	232	68.9 y	$\alpha$	
	233	$1.592 \times 10^5$ y	$\alpha$	
	<b>234</b>	$2.455 \times 10^5$ y	$\alpha$	
	<b>235</b>	$7.04 \times 10^8$ y	$\alpha, \gamma$	186, 144, 93
	236	$2.342 \times 10^7$ y	$\alpha$	
	237	6.75 d	$\beta^-, \gamma$	60, 101, 208
	<b>238</b>	$4.468 \times 10^9$ y	$\alpha$	
	240	14.1 h	$\beta^-$	
	<b>93 Np</b>	234	4.4 d	$\gamma$
235		1.084 y	$\epsilon$	
236		$154 \times 10^3$ y	$\gamma$	98, 160, 95
236m		22.5 h	$\gamma$	98, 95, 111
<b>237</b>		$2.144 \times 10^6$ y	$\alpha, \gamma$	86, 96
238		2.117 d	$\beta^-, \gamma$	984, 1029, 1026

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$	
<b>93 Np</b>	239	$\beta^{-}, \gamma$	106, 104, 278	
	240	$\beta^{-}, \gamma$	566, 974, 601	
<b>94 Pu</b>	234	$\epsilon$		
	236	$\alpha$		
	237	$\gamma$	101, 97, 114	
	<b>238</b>	$\alpha$		
	<b>239</b>	$2.411 \times 10^4$ y	$\alpha$	
	240	6564 y	$\alpha$	
	241	14.29 y	$\beta^{-}$	
	242	$3.75 \times 10^5$ y	$\alpha$	
	243	4.956 h	$\beta^{-}, \gamma$	84
	244	$8.00 \times 10^7$ y	$\alpha$	
	245	10.5 h	$\beta^{-}, \gamma$	327, 106, 102
	246	10.84 d	$\beta^{-}, \gamma$	224, 106, 102
	247	2.27 d	$\beta^{-}$	
	<b>95 Am</b>	237	$\gamma$	280, 104, 100
238		$\gamma$	104, 963, 919	
239		$\gamma$	104, 100, 117	
240		2.117 d	$\gamma$	988, 104, 889
<b>241</b>		432.2 y	$\alpha, \gamma$	60
242		16.02 h	$\beta^{-}, \gamma$	104, 100, 117
242m		141 y	$\gamma$	
<b>243</b>		7370 y	$\alpha, \gamma$	75
244		10.1 h	$\beta^{-}, \gamma$	744, 898, 154
245		2.05 h	$\beta^{-}, \gamma$	253, 109, 105
<b>96 Cm</b>		238	$\epsilon$	
	239	$\approx 2.9$ h	$\epsilon$	
	240	27 d	$\alpha$	
	241	32.8 d	$\gamma$	472, 106, 102
	<b>242</b>	162.8 d	$\alpha$	
	243	29.1 y	$\alpha, \gamma$	104, 278, 100
	<b>244</b>	18.1 y	$\alpha$	
	245	8500 y	$\alpha, \gamma$	104, 100, 117
	246	4760 y	$\alpha$	
	247	$1.56 \times 10^7$ y	$\alpha, \gamma$	402, 278, 287
	248	$3.48 \times 10^5$ y	$\alpha$	
	249	1.069 h	$\beta^{-}$	
	250	$\approx 8.3 \times 10^3$ y	SF	
<b>97 Bk</b>	243	4.5 h	$\epsilon$	
	244	4.35 h	$\epsilon$	
	245	4.94 d	$\gamma$	109, 105, 253
	246m	1.8 d	$\gamma$	799, 109, 105
	247	1380 y	$\alpha, \gamma$	84, 265, 106
	248m	23.7 h	$\beta^{-}, \gamma$	109, 105, 551
	249	330 d	$\beta^{-}$	
	250	3.212 h	$\beta^{-}, \gamma$	989, 1032, 1029
<b>98 Cf</b>	246	1.488 d	$\alpha$	
	247	3.11 h	$\gamma$	112, 107, 126
	248	333.5 d	$\alpha$	
	249	351 y	$\alpha, \gamma$	388, 333, 109
	250	13.08 y	$\alpha$	

**Table I - Nuclide Properties  $T_{1/2} \geq 1$  h**

<b>Nuclide</b>	<b>Half-life</b>	<b>Major Radiations</b>	<b>Major <math>\gamma</math>-rays (keV) <math>I_{\gamma} &gt; 2\%</math></b>	
<b>98 Cf</b>	251	898 y	$\alpha, \gamma$	109, 177, 105
	<b>252</b>	2.645 y	$\alpha$	
	253	17.81 d	$\beta^-$	
	254	60.5 d	SF	
	255	1.417 h	$\beta^-$	
<b>99 Es</b>	249	1.703 h	$\gamma$	379, 115, 110
	250	8.6 h	$\gamma$	115, 829, 110
	250m	2.22 h	$\gamma$	115, 110, 129
	251	1.375 d	$\gamma$	115, 110, 129
	252	1.291 y	$\alpha, \gamma$	785, 139, 115
	<b>253</b>	20.47 d	$\alpha$	
	254	275.7 d	$\alpha, \gamma$	70, 63
	254m	1.637 d	$\beta^-, \gamma$	649, 694, 689
	255	39.8 d	$\beta^-$	
	256m	7.6 h	$\beta^-, \gamma$	862, 231, 173
<b>100 Fm</b>	251	5.3 h	$\gamma$	118, 113, 133
	252	1.058 d	$\alpha$	
	253	3 d	$\gamma$	118, 113, 133
	254	3.24 h	$\alpha$	
	<b>255</b>	20.07 h	$\alpha$	
	256	2.627 h	SF	
	257	100.5 d	$\alpha, \gamma$	115, 110, 129

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
101	154Eu,173Lu,230Ra,237Pu,237U
102	131mTe,153Tb,241Cm,245Pu,246Pu,247Bk
103	153Gd,153mSm,196mIr
104	163Tm,236Np,237Am,238Am,239Am,239Np,240Am,242mAm,243Cm 245Cm
105	155Eu,155Tb,177mLu,184mRe,228Pa,229Ac,229Pa,230Pa,245Bk 246mBk,248mBk,251Cf
106	187Pt,188mRe,239Np,241Cm,245Pu,246Pu,247Bk
107	247Cf
108	151Tb,183Ta,231U
109	66Ge,245Am,245Bk,246mBk,248mBk,251Cf
110	153Tb,169Yb,187Pt,249Es,250Es,251Es,257Fm
111	125mXe,184mRe,184Ta,233Pa,234Np,234Pa,236Np
112	48Cr,171Er,194mIr,247Cf,256mEs
113	177mLu,177Ta,251Fm,253Fm
114	139mNd,149Nd,182Hf,183mOs,237Pu,237U
115	146Gd,177W,249Es,250Es,251Es,256mEs,257Fm,257Md
116	146Gd,177W
117	166Ho,229Ac,237Am,238Am,239Am,239Np,240Am,243Cm,245Cm
118	181Os,251Fm,253Fm
119	103Ag,190mRe
120	147Tb,170Hf,184Ir,241Cm,245Pu,246Pu
121	75Se,147Eu,256mEs,257Md
122	57Co,90Mo,152mEu,177mLu
123	154Eu,154mTb,179mHf,245Bk,246mBk,251Cf
124	131Ba,171Er,173Hf
125	127Cs,127Xe
126	100Pd,172Hf,175Ta,247Cf
127	57Ni,101Rh
128	134mCs
129	129Ba,177mLu,191mIr,191Os,249Es,250Es,251Es,257Fm
130	77Kr,105Ru
131	133mCe,169Yb,182Re,224Ac,234Pa
133	181Hf,251Fm
134	144Ce,187W,197Hg
135	229Ac,256mEs
136	57Co,75Se,116mSb,181Hf,257Md
137	166Ho,186Ir,186Re,204Po
139	184Hf,252Es
140	147Tb,173Hf
141	75Br,90Nb,99Tc,125mXe,154mTb
143	46mSc,71mZn
144	235U
145	72Zn,141Ce
146	179mHf,229Ac
147	77Kr
148	103Ag,196mAu,200Pb,230Ra
149	123Xe
150	131mTe,149Gd,177Yb,232Pa
151	85mKr,85mSr
152	182Re,182Ta,197Tl
153	136Cs,177mLu,234Pa,240Np
154	119mTe,151Gd,223Ra,244Am
155	132Ce,146Gd,188Ir,188mRe
156	149Nd,182Hf,182Re



**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
157	192Hg
158	56Ni,199Au,226Ac
159	47Sc,117mIn,117Sb,117Sn,123I,123mTe
160	152mTb,236Np
161	183Ta,184mRe
162	173Hf,183Re
163	90Mo,140Ba,235U
165	149Tb,170Hf,229Ac
166	139Ba,139Ce,156Sm
167	201mTl
168	151Pm,183mOs,196mAu
169	52Fe,182Re,211Rn
170	153Tb,179mHf
171	111In
172	111mPd,127Xe,173Ta
173	127Xe,198Pb,256mEs
174	177mLu
175	48Sc,71As,80Sr,132mI,245Cm
176	125Sb
177	136Cs,169Yb,251Cf
178	123Xe,208At
179	257Fm
180	151Tb,155Tb,182Os,198mAu,246Pu
181	99Mo,184Hf,200mAu
182	66Ge,132Ce,172Lu
184	166Ho,166Tm,168Tm,206Bi,230Ra
185	67Cu,67Ga,162mHo
186	177W,193Au,235U
187	190Ir,190mRe,193Hg
188	125mXe,188Pt,196mAu
189	230Ra
190	66Ge,81Rb,114mIn
191	169Lu,182Re
192	72Zn
193	179mHf,240Np
195	188Pt,209At
196	88Kr
197	120mSb,147Eu,160mHo,160Tb
198	101Rh,168Tm,169Yb
199	156mTb
201	131mTe
202	176Lu,176Ta,187Pt
203	90Mo,90mY,127Xe,172Lu,230Ra
204	95mTc,109Cd,109In,156Sm,177mLu,198mAu
205	208At,235U
207	135Ce,174Ta,175Ta
208	167Tm,177mLu,199Au,199Tl,237U
211	77Ge,103mRu,149Nd,161Er
212	121I,121mTe,153Tb,230Ra
213	103mRu,178mHf,178Ta,200mTl
214	129Ba,153Dy,177mLu,179Lu
215	166Tm,180mHf,184Ta,198mAu
216	77Ge,97Ru,131Ba,206mTl,224Ac
217	178mHf,179mHf,184mRe,189Re
218	256mEs

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
221	129Ba
222	106mAg,106Rh,182Re,182Ta
224	182Hf,246Pu
226	154mTb,198Tl
227	155Dy,184Ta,234Pa,251Cf
228	132Te,177mLu,239Am,239Np,243Cm
229	147Gd,182Re
230	226Ac
231	256mEs
232	85mSr,85mY
233	133mXe
234	126Ba,177mLu
236	95Nb,179mHf,227Th
237	178mHf
238	167Ho
239	77Br,181Os,209At,212Pb
241	126Ba,131mTe,163Tm,257Fm
242	214Pb
243	86Zr,125mXe,151Gd,165Tm,181Os
244	103Ag,183Ta,189Pt
245	111In,152mEu,189Ir,210At,229Ac
246	66Ge,183Ta
247	199Tl,206mTl
248	154Eu,154mTb
250	135Xe,177mLu,211Rn
252	76Kr,127Sb,151Tb,229Ac,230Ra
253	184mRe,184Ta,245Am,245Bk
254	118mSb,137mCe,153Dy,185Ir,226Ac
256	182Re,193Au,200mAu,227Th
257	90Mo,152Dy
258	126Ba,178mHf,193Hg
260	109Cd,198Pb
261	79Kr
262	155Tb,195mHg,207Bi,229Ac
263	93Mo,105Ru,156mTb,182Os
264	77Ge,184Ir,203Bi
265	75Ge,75Se,247Bk
266	135Ce,206mTl,210mBi
267	93Y,103Ag,175Ta
268	135mBa,149Nd
269	179mHf,223Ra
270	56Ni,76Kr,101Pd,149Nd,182Hf,204Po
271	44Sc,119mTe,152mTb,219Rn,240Np
272	173Lu
273	66Ge,117mCd,128Ba
274	136Cs
275	151Pm,192Hg
276	133mBa,182Re
277	78Ge,152mTb,208Tl
278	191Au,239Am,239Np,243Cm
279	197Hg,203Hg,203Pb
280	75Se,105Ag,166Ho,237Am
281	182Re
282	177mLu
283	61Cu,110Sn,152mTb,162mHo,198Tl

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
284	131I,191Au
285	230Ra
286	206Po
287	75Br,151Tb,182Re
288	148mPm,229Ac
290	198Pb
291	229Ac
293	143Ce
294	194Au
295	190Ir,214Pb
296	101Pd,171Er,177mLu,192Au,192Ir,210Tl
297	73Ga,165Tm,173Hf,178mHf,186Ir
299	113Ag,149Gd,160Tb
300	67Ga,135Ce,233Pa
301	207At
303	133mBa,138mPr,250Es
305	85mKr,210mBi
306	105Rh
307	101Rh,173Hf,176Lu,192Hg
308	48Cr,169Yb,171Er,192Ir
311	173Hf
312	114mIn,233Pa
314	128Sb
315	117mIn
316	76Kr,105Ru,179mHf
317	192Au,192Ir,229Ac
318	184mRe,184Ta
319	105Rh,177mLu
320	51Cr,195mIr,229Ac
321	167Ho
322	99Rh
323	90Mo
324	97Ru
325	101Rh
326	73Ga,157Dy,178mHf,178Ta
327	245Pu
328	177mLu,194mIr
329	140La,194Au,194mIr
330	123Xe
331	201Pb,201mTl
332	178Ta,180mHf
333	196mAu,249Cf
334	131mTe,150Eu,150Pm,198mAu
336	95Ru,115Cd,115mIn
338	66Ge,206Po,228Ac,228Pa
339	182Re,194mIr
340	151Pm,182Hf
341	99Rh,136Cs
342	111Ag
343	175Hf
344	117mCd,152mEu,152mTb,182Hf,206Bi,206Pb
345	105Ag,184Hf
346	181Hf
347	149Gd,154mTb,167Ho,197mPt
349	175Ta,250Es

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
350	122Xe
351	182Re,211Bi
352	149Tb,214Pb
353	99Rh,199Pb
354	183Ta
356	133mBa,156mTb,196mAu,196mIr
360	191Pt
361	73Se,181Re,190Ir,190mRe,201Pb
363	179mHf
364	131I,159Gd
365	195mIr,198Pb
366	181Re
367	77Ge,199Pb
368	200mAu,200mTl
370	147Gd
371	157Eu,190Ir,190mRe,257Md
372	129Cs
373	43K,43Sc,131Ba
375	127Xe,204Bi,204mPb
379	177mLu
380	249Es
381	87Y,188Pt
382	66Ge,83Sr,183mOs,193Hg,198Pb
384	133mBa,184Ta,250Es
386	71mZn
387	158Er
388	232Pa,249Cf
389	87mSr,87Y,126I,149Tb
390	184Ir,202mPb
391	138mPr,194mIr
392	113mIn,113mSn
393	88Zr
394	196mIr
395	151Tb
396	147Gd,175Yb
397	43K,190Ir,190mRe
398	79Kr,206Bi
399	173Tm
401	28Mg,75Se
402	219Rn,247Cm
403	87Kr
405	229Ac
406	106mAg,106Rh,207Po
407	76Kr,116mSb,150Pm,172Er,190Ir,190mRe,229Ac
408	193Hg
409	191Pt,228Pa
410	179mHf
411	129Cs,152mTb,157Eu,166Ho
412	127Cs,198mAu,198Tl
414	148Eu,148mPm,177mLu,184Ta
415	126Sb
416	77Ge
417	177W
418	130I
419	102Rh,177mLu

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
422	156mTb,202Bi,202mPb
423	229Ac
424	149Nd
426	178mHf,178Ta,196mAu,196mTl,197Tl,207Bi
427	154mTb,177W
428	125Sb
429	106Rh
430	106mAg
433	148mPm,195mIr
434	108mAg,117mCd
435	186Ir
436	229Ac
438	127Sn,237Am
439	69mZn,150Eu
440	202Tl,213Bi
442	211Rn
443	86Y,105Ag,180mHf
444	151Tb,230Pa
445	90Mo
446	81Rb,100Rh
447	196mIr
448	168Tm,240Np
449	229Ac,230Ra
451	106mAg,106Rh
452	76Kr,131mTe
453	206mTl
454	146Pm,178mHf,179mHf,232Pa
455	199Tl,230Pa
456	182Hf,207Bi
457	206mTl
458	206Pb,230Ra
459	183Hf
460	96Nb,129mTe,202mPb
461	173Tm,184Ta
462	127Cs
463	125Sb,228Pa
465	132La,149Tb
467	207At
468	192Ir
469	105Ru
470	230Ra
471	66Ge
472	24mNa,152mTb,241Cm
473	127Sb
475	102Rh
477	55Co,133mCe,144Pm
478	188Ir
479	151Tb,229Ac,230Ra
480	56Ni,90mY,187W
481	96Nb
482	181Hf
483	194mIr
485	87Y
487	71mZn,140La
489	47Ca,148Tb

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
490	202mPb
491	127Sn
492	115Cd
493	184Ir
495	178mHf
496	131Ba,150Tb
497	103mRu,206Bi
498	200mAu
501	148mPm,180mHf
503	190Ir
504	85mY
505	196mTl
507	89mNb,182Hf
508	62Zn,97Zr,121mTe
509	230Ra
510	81Rb,133mCe,182Os
511	many
512	71mZn,106mAg,106Rh
514	85mSr
516	206Bi,206Pb,232Pa
517	208At
518	135Ce,154mTb
519	190Ir,190mRe
520	83Rb
521	77Br,196mIr
522	206Po
523	132mI
527	128Sb,229Ac
528	99Rh,115Cd
530	83Rb,133I,166Ho
531	147Nd
532	103Ag,121I
534	156mTb
535	178mHf,204Po
536	130I
537	66Ge,111In,140Ba,184Ta,193Hg,206Bi,206Pb
539	191Pt,200mTl
540	100Rh,132La,154mTb,184Ir,229Ac
541	149Nd
543	116mSb
545	129Sb,189Pt,209At
547	135I
548	62Zn,138mPr
550	148Eu,148mPm
552	187W
553	80Sr,83Rb,148Eu
554	82Br,82mRb
555	147Tb
556	104Ag
558	77Ge,154mTb,190Ir,190mRe
559	76As,76Br,147Gd,190mRe
560	120I,195mHg,245Pu
561	92Nb,238Am
562	194mIr,229Ac
563	134mCs

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
564	117mCd,122Sb,195Tl,206mTl
566	240Np
567	132La
569	96Nb,134mCs,189Pt,190Ir,190mRe,229Ac
570	207Bi,207mPb,234Pa
571	166Ho,207Bi
572	135Ce,148Eu
573	121mTe,170Hf,193Hg
574	69Ge,126Sb,178mHf
576	229Ac
577	135Ce
579	200mAu,200mTl,202Bi
580	205Bi
581	232Pa
582	95mTc,110In
583	208Tl
584	110In,150Eu,186Ir
586	152mTb,191Au
587	151Tb,198Tl
588	89mNb,100Rh,201mTl,207At
589	80Sr
590	101Pd
593	43K,126Sb
596	71mZn,74As
597	62Zn,123mCs
600	132mI,148mPm
601	72Ga,120I,125Sb,147Eu,194mIr,240Np
603	124I,124Sb,182Hf
604	192Ir
605	134mCs,190Ir,190mRe,229Ac,238Am
606	79Kr
607	125Sb,135Ce
608	189Pt
609	214Bi
610	103mRu,172Er
611	148Eu,148mPm,196mTl
612	86Zr,177W,186Pt,192Ir
614	78As,108mAg
616	106mAg,106Rh
617	43K,112Ag,151Tb,190Ir
618	99Rh,144Pm,187W
619	82Br,82mRb
620	71mZn,206Bi
621	170Hf
622	52Fe,106Rh
624	109In
627	95Ru
628	86Y,102Rh
629	128Sb,201Bi
630	72As,72Ga,132mI,148Eu,148mPm,186Ir
631	102Rh
632	77Ge,148Tb,168Tm
633	146Eu,188Ir
634	146Eu
635	74As,196mTl

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
636	125Sb,128Sb,186Ir
637	131I,198Tl
638	150Tb
639	181Re
641	120I,142La
642	110In
644	119mTe
645	105Ag,160mHo
646	86Y,124Sb,156Eu,185Os
647	196mIr
649	154mTb,254mEs
652	98Tc,149Tb
653	91Sr
654	128Sb,145Eu
655	149Nd
656	61Cu
657	76As,76Br,202Bi,202mPb
658	97Nb,110mAg,110In,207At
660	208At
662	137Cs
663	132La
665	143Ce,146Eu
666	126I
667	126Sb,171Lu
668	132Cs,132mI
669	130I
670	207Bi
671	166Ho,204Bi
672	166Tm
673	190mRe
674	191Au,211Rn
675	207At
676	105Ru,198Tl
678	110mAg,147Eu,211Rn,256mEs
680	204Po
684	129Sb
685	93Mo,195mIr
686	127Sb,187W
687	110mAg,206mTl,208At
688	194mIr
689	186Pt,254mEs
691	166Tm
694	147Tb,254mEs
695	78As,126Sb,196mTl
696	144Pm
697	102Rh,126Sb,172Lu
698	82Br,82mRb
700	119mTe
703	86Y,94mNb,94Tc,205Bi
705	166Tm
707	110mAg,110In
708	139mNd
709	187Pt
711	176Ta
712	166Ho



**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
714	77Ge,207Bi
717	106mAg,106Rh
720	96Nb,117Te,168Tm,199Pb
721	126Sb,189Pt,207At
722	143Ce,154mTb
723	108mAg,124I,124Sb,154Eu,156Eu
724	95Zr,105Ru
726	148Eu,148mPm
727	212Bi
728	160mHo
731	151Tb,168Tm
733	234Pa
736	146Pm
737	150Eu
738	139mNd
740	99Mo,130I,171Lu
741	104Ag,168Tm
742	143Pm
743	97Zr,128Sb,207Bi,207Po,234Np
744	52Mn,244Am
745	98Tc
747	146Eu,146Pm
748	106mAg,150Eu
749	106Rh,149Gd
750	56Ni,91Sr
752	166Ho
754	128Sb,139Ce
757	95Zr
759	104Ag
760	200mAu
763	83Sr,204Po,256mEs
764	110mAg
766	95Nb,95mTc,147Gd
767	102Rh,186Ir
768	104Ag,186Ir
770	89mNb
773	132mI,186Ir
774	131mTe
777	82Br,82mRb,86Y
778	96Nb,96Tc
779	152mEu,152mTb,166Tm
780	195mHg
782	131mTe,209At
783	50V
784	127Sb,135Ce,148Tb,183Hf
785	133mCe,252Es
786	95mTc,104Ag,166Tm,201Bi
787	202mPb
788	181Os
789	138La,138mPr,149Gd
790	209At
792	184mRe,184Ta
793	106mAg
794	106Rh,131mTe
796	134mCs

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
799	246mBk
800	182Hf,210Tl
802	134mCs,139mNd
803	206Bi,206Pb
804	106mAg
805	106Rh
806	127Sn,165Tm
807	206Po,208At
808	47Ca,106Rh
810	96Nb,139mNd,166Ho,172Lu,250Es
811	58mCo
812	56Ni,132mI,156Eu
813	96Tc,129Sb,249Es
814	128Sb,207At
816	140La,168Tm
817	149Tb
818	110mAg
819	136Cs,201Bi,232Pa
820	203Bi
821	168Tm
823	100Rh,127Sn,131mTe
825	106mAg,106Rh,127Sn,203Bi
827	161Er,181Os
828	78As,82Br,82mRb,135Ce,139mNd,200mTl
829	188Ir,250Es
830	168Tm
831	166Ho
832	150Pm,181Os
834	66Ga,72As,72Ga,256mEs
835	54Mn,88Kr,95mTc
836	196mIr
837	135I,205Po
841	184Ir
842	152mEu
844	116mSb
845	87Kr,208At
847	56Co,56Mn,203Bi
850	94Tc,96Nb,96Tc,205Po
852	131mTe
853	149Tb
857	126Sb
858	104Ag
860	117mCd,127Sn,210Tl
861	193Hg,208Tl
862	149Tb,256mEs
863	104Ag
865	198Pb
866	211Rn
867	232Pa,240Np
868	140La
870	52Fe,148Eu
871	94mNb,94Tc
872	69Ge,160mHo,205Po
873	154Eu,154mTb
875	185Os

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>	<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
876	150Pm	961	169Lu,184Ir,202Bi,202mPb
879	160mHo,160Tb	962	160mHo,160Tb
881	185Os,206Bi,206Pb,234Pa	963	152mEu,238Am
882	84Rb	964	152mEu
883	234Pa	965	228Pa
884	195Tl,204Po	966	129Sb,160mHo,160Tb
885	110mAg,110In	969	228Ac,228Pa,232Pa
889	46mSc,240Am	973	116mSb
890	169Lu	974	240Np
894	72Ga,145Eu,147Gd,232Pa	976	207Bi
895	142La,184mRe,184Ta,206Bi	979	127Sn
896	240Np	980	206Po
897	203Bi,208At	982	139mNd
898	88Y,244Am	984	48Sc,48V,204Bi,238Np
899	204Bi,204mPb,230Pa	985	170Lu
901	172Lu	987	186Ir
902	201Bi	988	205Bi,240Am,240Np
903	184mRe,184Ta	989	250Bk,250Es
904	200mAu	990	126Sb,208At
907	207At	992	207Po
908	201Pb	993	154mTb
909	89Zr	996	154Eu,154mTb
910	139mNd	997	110In
911	228Ac,228Pa	1001	205Po
912	172Lu,204Bi,204mPb,207Po	1003	172Lu
913	119mTe	1005	154Eu,154mTb
914	85mY	1008	82mRb
915	129Sb,148mPm	1014	148mPm,201Bi
916	94Tc	1016	204Po
918	204Bi,230Pa	1019	206Bi
919	238Am	1022	206mTl
921	184mRe,184Ta	1023	120mSb
923	104Ag	1024	91Sr
924	117Te	1026	238Np
925	140La,234Pa	1028	208At
926	104Ag	1029	117mCd,238Np
927	202Bi,234Pa	1030	129Sb
929	147Gd	1032	132La,206Po,250Bk
930	52Fe	1034	148Eu,203Bi
931	55Co	1035	183mOs
932	193Hg,207Bi	1036	177W
933	186Ir	1038	48Sc,56Co,138mPr
934	92Nb,92Y	1039	66Ga,135I
935	92Nb	1040	204Po
936	52Mn,201Bi	1044	82Br,82mRb,205Bi
937	110mAg,110In,162mHo	1045	184Ir
941	28Mg	1046	106mAg
942	90Mo,104Ag,119mTe	1047	102Rh,106Rh
943	182Hf	1048	136Cs
944	48V	1049	150Eu
946	201Pb,234Pa	1051	72Ga,118mSb
947	211Rn	1052	256mEs
952	230Pa	1060	181Os
954	202Bi	1064	207Bi,207mPb
955	132mI,181Os	1065	156mTb

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>	<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
1066	117mCd	1194	234Np
1067	125Sn	1199	106mAg
1069	147Gd	1200	96Nb
1070	210Tl	1201	106Rh,198Tl
1072	116mSb	1206	200mTl
1076	182Re	1207	131mTe
1077	86Rb,86Y,147Eu	1210	188Ir,210Tl
1079	148Tb	1213	119mTe
1081	177Yb,246mBk	1216	76Br
1085	77Ge	1220	162mHo
1086	152mEu	1221	182Re,182Ta
1091	96Nb,117Te	1222	156mTb,182Re
1093	256mEs	1223	106mAg
1094	172Lu,172Tm	1224	106Rh
1096	127Sn	1225	176Ta
1097	95Ru	1230	118mSb
1098	206Bi	1231	156Eu,182Re,182Ta
1099	59Fe	1235	117mCd,136Cs
1102	183mOs	1238	56Co,214Bi
1103	209At	1240	78As
1105	184Ir	1242	156Eu,174Lu
1107	69Ge,100Rh	1260	135I
1108	183mOs	1261	99Rh
1110	210Tl	1265	163Tm
1112	152mEu	1272	160Tb
1113	102Rh	1274	103Ag,154Eu,154mTb,166Tm
1114	127Sn	1275	22Na
1116	65Ni,65Zn	1280	170Lu
1119	193Hg	1291	154mTb
1120	214Bi	1292	59Fe
1121	46mSc,182Re,182Ta	1294	41Ar,116mSb
1123	154mTb	1297	47Ca,146Eu
1125	131mTe	1299	206Pb
1127	96Tc,211Rn	1303	117mCd
1128	106mAg,106Rh	1309	78As
1129	90Nb	1312	48Sc,48V
1131	147Gd	1316	210Tl
1132	135I	1317	55Co,82Br,82mRb
1135	199Pb	1325	150Pm,201Bi
1137	119mTe	1332	60Co
1140	206mTl	1334	52Mn
1148	207Po	1342	28Mg,100Rh,104Ag
1152	147Tb	1362	100Rh
1153	86Y	1363	93Tc,211Rn
1154	156Eu,156mTb	1364	195Tl
1157	44Sc,130I	1369	24mNa,206Pb
1159	156mTb,176Ta	1374	166Tm
1166	150Pm	1378	57Ni
1172	120mSb	1384	92Sr,110mAg
1173	60Co	1387	172Tm
1177	166Tm	1388	112Ag
1178	160Tb	1398	163Tm
1179	95Ru	1399	132mI
1181	210At	1408	152mEu
1189	182Re,182Ta	1409	55Co

**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>	<b>E<math>\gamma</math></b>	<b>Parent Nuclide</b>
1416	52Fe	1770	207Bi
1420	154mTb	1771	56Co
1421	198Tl	1791	135I
1422	156mTb	1809	26Al
1427	182Re	1811	56Mn
1433	117mCd	1829	185Ir
1434	52Mn,163Tm	1836	88Y
1435	234Np	1847	203Bi
1436	138La	1854	76Br,86Y
1437	210At	1861	72Ga
1450	169Lu	1862	205Bi
1458	135I	1863	148Tb
1461	40K	1879	238U
1465	148mPm	1893	203Bi
1469	194Au	1901	142La
1475	82Br,82mRb	1910	132La
1477	93Mo,93Tc	1920	57Ni
1482	65Ni	1921	86Y
1483	210At	1930	100Rh
1496	196mTl	1942	38S
1505	110mAg	1997	117mCd,145Eu,154mTb
1520	93Tc	2003	127Sn
1523	120I	2010	210Tl
1525	42K	2035	56Co
1527	104Ag,234Np	2038	52Fe
1528	106mAg	2040	198Tl
1529	106Rh	2042	170Lu
1530	88Kr,172Tm	2052	166Tm
1534	146Eu	2060	188Ir
1537	203Bi	2064	154mTb
1553	100Rh	2080	166Tm
1554	50V	2091	124Sb
1558	234Np	2096	117mCd
1562	56Ni	2097	188Ir
1571	234Np	2103	132La
1572	106mAg	2113	56Mn
1574	106Rh	2186	90Nb
1577	117mCd	2187	154mTb
1584	176Ta	2190	66Ga
1595	206Bi	2196	88Kr
1596	140La	2202	72Ga
1600	210At	2204	214Bi
1602	234Np	2215	188Ir
1626	104Ag	2237	192Au
1651	201Bi	2300	117Te
1658	199Pb	2319	90Nb
1659	145Eu	2323	117mCd
1678	135I	2360	210Tl
1680	203Bi	2376	100Rh
1691	124I,124Sb	2392	88Kr
1716	117Te,188Ir	2398	142La
1719	206Bi	2430	210Tl
1736	150Pm	2491	72Ga
1758	57Ni	2508	72Ga
1764	205Bi,214Bi	2513	238U

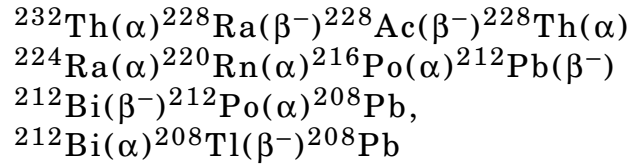
**Table II.  $\gamma$ -rays, energy (keV) ordered ( $I_{\gamma} \geq 5\%$ )**

<b><math>E_{\gamma}</math></b>	<b>Parent Nuclide</b>
2543	142La
2555	87Kr
2598	56Co
2614	208Bi
2615	208Tl
2752	66Ga
2754	24mNa
2793	76Br
2951	76Br

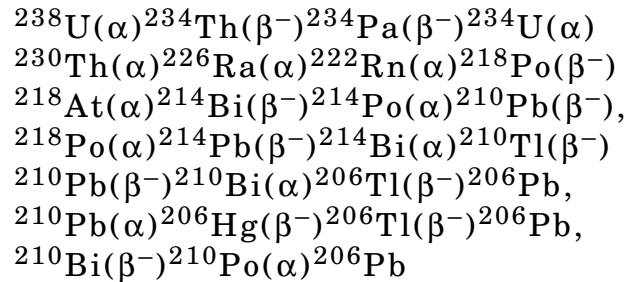
## Naturally-Occuring Decay Chains

The following three radioactive decay chains occur in nature:

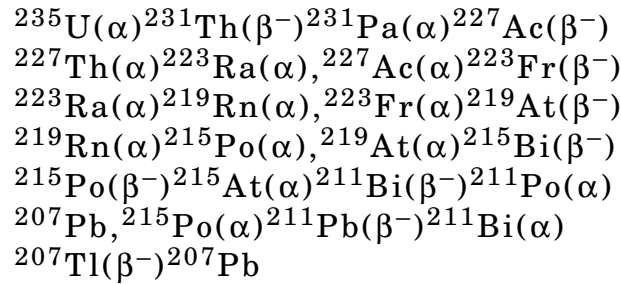
### The Thorium Series:



### The Uranium Series:



### The Actinium Series



## Radioactive Nuclides in Nature

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$
<b>1 H 3</b>	12.32 y	$\beta^-$	
<b>6 C 14</b>	5700 y	$\beta^-$	
<b>19 K 40</b>	$1.265 \times 10^9$ y	$\beta^-, \gamma$	1461
<b>23 V 50</b>	$1.4 \times 10^{17}$ y	$\gamma$	1554, 783
<b>37 Rb 87</b>	$4.81 \times 10^{10}$ y	$\beta^-$	
<b>48 Cd 113</b>	$7.7 \times 10^{15}$ y	$\beta^-$	
<b>49 In 115</b>	$4.41 \times 10^{14}$ y	$\beta^-$	
<b>57 La 138</b>	$1.02 \times 10^{11}$ y	$\gamma$	1436, 789
<b>60 Nd 144</b>	$2.29 \times 10^{15}$ y	$\alpha$	
<b>62 Sm 147</b>	$1.06 \times 10^{11}$ y	$\alpha$	
<b>148</b>	$7 \times 10^{15}$ y	$\alpha$	
<b>64 Gd 152</b>	$1.08 \times 10^{14}$ y	$\alpha$	
<b>71 Lu 176</b>	$4.00 \times 10^{10}$ y	$\beta^-, \gamma$	307, 202, 56
<b>72 Hf 174</b>	$2.0 \times 10^{15}$ y	$\alpha$	
<b>73 Ta 180m</b>	$> 1.2 \times 10^{15}$ y	$\beta^-$	
<b>75 Re 187</b>	$4.35 \times 10^{10}$ y	$\beta^-$	
<b>76 Os 186</b>	$2.0 \times 10^{15}$ y	$\alpha$	
<b>78 Pt 190</b>	$6.5 \times 10^{11}$ y	$\alpha$	
<b>90 Th 232</b>	$1.405 \times 10^{10}$ y	$\alpha$	
<b>92 U 235</b>	$7.04 \times 10^8$ y	$\alpha, \gamma$	186, 144, 93
<b>238</b>	$4.468 \times 10^9$ y	$\alpha$	



## Some Well-known Radionuclides

Nuclide	Half-life	Major Radiations	Major $\gamma$ -rays (keV) $I_{\gamma} > 2\%$	
<b>11 Na</b> 22	2.602 y	$\gamma$	511, 1275	
<b>24 Cr</b> 51	27.7 d	$\gamma$	320	
<b>25 Mn</b> 56	2.579 h	$\beta^{-}, \gamma$	847, 1811, 2113	
<b>26 Fe</b> 59	44.5 d	$\beta^{-}, \gamma$	1099, 1292	
<b>27 Co</b> 57	271.7 d	$\gamma$	122, 136	
	60	5.271 y	$\beta^{-}, \gamma$	1332, 1173
<b>29 Cu</b> 64	12.7 h	$\gamma$	511	
<b>31 Ga</b> 66	9.49 h	$\gamma$	511, 1039, 2752	
	67	3.261 d	$\gamma$	93, 185, 300
	68	1.127 h	$\gamma$	511, 1077
<b>34 Se</b> 75	119.8 d	$\gamma$	265, 136, 280	
<b>38 Sr</b> 85	64.84 d	$\gamma$	514	
	85m	1.127 h	$\gamma$	232, 151
	90	28.79 y	$\beta^{-}$	
<b>43 Tc</b> 99m	6.015 h	$\gamma$	141	
<b>44 Ru</b> 103	39.26 d	$\beta^{-}, \gamma$	497, 610	
	106	1.023 y	$\beta^{-}$	
<b>45 Rh</b> 106m	2.183 h	$\beta^{-}, \gamma$	512, 1047, 717	
<b>47 Ag</b> 110m	249.8 d	$\beta^{-}, \gamma$	658, 885, 937	
<b>49 In</b> 111	2.805 d	$\gamma$	245, 171	
<b>53 I</b> 123	13.27 h	$\gamma$	159	
	131	8.021 d	$\beta^{-}, \gamma$	364, 637, 284
<b>55 Cs</b> 137	30.07 y	$\beta^{-}, \gamma$	662	
<b>56 Ba</b> 133	10.54 y	$\gamma$	356, 81, 303	
	133m	1.621 d	$\gamma$	276
<b>58 Ce</b> 144	284.9 d	$\beta^{-}, \gamma$	134	
<b>62 Sm</b> 153	1.929 d	$\beta^{-}, \gamma$	103, 70	
<b>67 Ho</b> 166	1.118 d	$\beta^{-}, \gamma$	81, 56	
	166m	$1.20 \times 10^3$ y	$\beta^{-}, \gamma$	184, 810, 712
<b>70 Yb</b> 169	32.03 d	$\gamma$	51, 63, 57	
<b>77 Ir</b> 192	73.83 d	$\beta^{-}, \gamma$	317, 468, 308	
	192m	1.45 m	$\gamma$	
	192m	241 y	$\gamma$	
<b>81 Tl</b> 201	3.038 d	$\gamma$	71, 69, 80	
<b>83 Bi</b> 207	32.9 y	$\gamma$	570, 1064, 75	
<b>95 Am</b> 241	432.2 y	$\alpha, \gamma$	60	

### List of Elements – Alphabetical

Name	Symbol	Z	Name	Symbol	Z
Actinium	Ac	89	Meitnerium	Mt	109
Aluminum	Al	13	Mendelevium	Md	101
Americium	Am	95	Mercury	Hg	80
Antimony	Sb	51	Molybdenum	Mo	42
Argon	Ar	18	Neodymium	Nd	60
Arsenic	As	33	Neon	Ne	10
Astatine	At	85	Neptunium	Np	93
Barium	Ba	56	Nickel	Ni	28
Berkelium	Bk	97	Niobium	Nb	41
Beryllium	Be	4	Nitrogen	N	7
Bismuth	Bi	83	Nobelium	No	102
Bohrium	Bh	107	Osmium	Os	76
Boron	B	5	Oxygen	O	8
Bromine	Br	35	Palladium	Pd	46
Cadmium	Cd	48	Phosphorus	P	15
Calcium	Ca	20	Platinum	Pt	78
Californium	Cf	98	Plutonium	Pu	94
Carbon	C	6	Polonium	Po	84
Cerium	Ce	58	Potassium	K	19
Cesium	Cs	55	Praseodymium	Pr	59
Chlorine	Cl	17	Promethium	Pm	61
Chromium	Cr	24	Protactinium	Pa	91
Cobalt	Co	27	Radium	Ra	88
Copper	Cu	29	Radon	Rn	86
Curium	Cm	96	Rhenium	Re	75
Darmstadtium	Ds	110	Rhodium	Rh	45
Dubnium	Db	105	Rubidium	Rb	37
Dysprosium	Dy	66	Ruthenium	Ru	44
Einsteinium	Es	99	Rutherfordium	Rf	104
Erbium	Er	68	Samarium	Sm	62
Europium	Eu	63	Scandium	Sc	21
Fermium	Fm	100	Selenium	Se	34
Fluorine	F	9	Seaborgium	Sg	106
Francium	Fr	87	Silicon	Si	14
Gadolinium	Gd	64	Silver	Ag	47
Gallium	Ga	31	Sodium	Na	11
Germanium	Ge	32	Strontium	Sr	38
Gold	Au	79	Sulfur	S	16
Hafnium	Hf	72	Tantalum	Ta	73
Hassium	Hs	108	Technetium	Tc	43
Helium	He	2	Tellurium	Te	52
Holmium	Ho	67	Terbium	Tb	65
Hydrogen	H	1	Thallium	Tl	81
Indium	In	49	Thorium	Th	90
Iodine	I	53	Thulium	Tm	69
Iridium	Ir	77	Tin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Tungsten	W	74
Lanthanum	La	57	Uranium	U	92
Lawrencium	Lr	103	Vanadium	V	23
Lead	Pb	82	Xenon	Xe	54
Lithium	Li	3	Ytterbium	Yb	70
Lutetium	Lu	71	Yttrium	Y	39
Magnesium	Mg	12	Zinc	Zn	30
Manganese	Mn	25	Zirconium	Zr	40

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