

|                     |                          |                          |                          |                           |                           |                           |                          |                            |                           |                        |                           |                            |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
|---------------------|--------------------------|--------------------------|--------------------------|---------------------------|---------------------------|---------------------------|--------------------------|----------------------------|---------------------------|------------------------|---------------------------|----------------------------|----------------------------|-------------------------|----------------------------|--------------------------|---------------------------|----------------------------|---------------------------------------------------------|------------------------|---------------------------|--------------------------|--------------------------|----------------------------|---------------------------|-------------------------------|------------------------------|------------------------------|----------------|------------------------------------------------------------|-------------------|
|                     |                          |                          |                          |                           |                           |                           |                          |                            | α: 100.00%                | α: 100.00%             | α: 100.00%                | ε: 60.00%<br>α: 40.00%     | α: 68.00%<br>ε: 32.00%     | ε≤ 97.00%<br>α≥ 3.00%   | ε: 98.00%<br>α: 2.00%      | ε: 100.00%<br>α: 2.0E-4% | ε: 100.00%<br>α≤ 1.0E-3%  | ε: 86.30%<br>β-: 13.50%    | α: 100.00%<br>sF≤ 2E-10%                                | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
|                     |                          |                          |                          |                           |                           |                           |                          |                            | 217U<br>16 MS             | 218U<br>0.51 MS        | 219U<br>42 μS             | 220U<br>≈60 NS             | 221U<br>700 NS             | 222U<br>1.0 μS          | 223U<br>18 μS              | 224U<br>0.9 MS           | 225U<br>84 MS             | 226U<br>0.26 S             | 227U<br>1.1 M                                           | 228U<br>9.1 M          | 229U<br>58 M              | 230U<br>20.8 D           | 231U<br>4.2 D            | 232U<br>68.9 Y             | 233U<br>1.592E+5 Y        | 234U<br>2.455E+5 Y<br>0.0054% | 235U<br>7.04E+8 Y<br>0.7204% | 236U<br>2.342E7 Y            | 237U<br>6.75 D | 238U<br>4.468E9 Y<br>99.2742%<br>α: 100.00%<br>sF: 5.5E-5% | 239U<br>2.34E10 Y |
|                     |                          |                          |                          |                           |                           |                           |                          |                            | α≤ 100.00%                | α: 100.00%             | α: 100.00%                | ε                          |                            | α: 100.00%              | α: 100.00%<br>ε: 0.20%     | α: 100.00%               | α: 100.00%                | α: 100.00%                 | α: 100.00%<br>ε < 5.00%                                 | ε≈ 80.00%<br>α≈ 20.00% | α: 100.00%<br>sF < 1E-10% | ε: 100.00%<br>α≈ 4.0E-3% | α: 100.00%<br>sF: 9E-20% | α: 100.00%<br>sF < 6.0E-9% | α: 100.00%<br>sF: 1.6E-9% | α: 100.00%<br>sF: 7.0E-9%     | α: 100.00%<br>sF: 9.4E-8%    | β-: 100.00%                  | β-: 100.00%    | β-: 100.00%                                                |                   |
| α: 100.00%          | 215Pa<br>14 MS           | 216Pa<br>0.15 S          | 217Pa<br>3.6 MS          | 218Pa<br>113 μS           | 219Pa<br>53 NS            | 220Pa<br>0.78 μS          | 221Pa<br>5.9 μS          | 222Pa<br>3.3 MS            | 223Pa<br>5.1 MS           | 224Pa<br>0.85 S        | 225Pa<br>1.7 S            | 226Pa<br>1.8 M             | 227Pa<br>38.3 M            | 228Pa<br>22 H           | 229Pa<br>1.50 D            | 230Pa<br>17.4 D          | 231Pa<br>3.276E+4 Y       | 232Pa<br>1.32 D            | 233Pa<br>26.975 D                                       | 234Pa<br>6.70 H        | 235Pa<br>24.44 M          | 236Pa<br>9.1 M           | 237Pa<br>8.7 M           | 238Pa<br>2.2E10 Y          |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%          | α: 100.00%               | α≈ 98.00%<br>ε≈ 2.00%    | α: 100.00%               | α: 100.00%                | α: 100.00%                | α: 100.00%<br>ε: 3.0E-7%  | α: 100.00%               | α: 100.00%                 | α: 100.00%                | α: 100.00%             | α: 100.00%                | α: 100.00%                 | α: 74.00%<br>ε: 26.00%     | α: 85.00%<br>ε: 15.00%  | ε: 98.00%<br>β-: 2.00%     | ε: 99.52%<br>β-: 0.48%   | ε: 92.20%<br>β-: 7.80%    | α: 100.00%<br>sF≤ 3E-10%   | β-: 100.00%<br>ε: 3.0E-3%                               | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%                   | β-: 100.00%                  | β-: 100.00%<br>sF < 2.0E-10% |                |                                                            |                   |
| α: 100.00%          | 214Th<br>100 MS          | 215Th<br>1.2 S           | 216Th<br>26.0 MS         | 217Th<br>0.241 MS         | 218Th<br>117 NS           | 219Th<br>1.05 μS          | 220Th<br>9.7 μS          | 221Th<br>1.68 MS           | 222Th<br>2.237 MS         | 223Th<br>0.60 S        | 224Th<br>0.81 S           | 225Th<br>8.72 M            | 226Th<br>30.57 M           | 227Th<br>18.68 D        | 228Th<br>1.9116 Y          | 229Th<br>7340 Y          | 230Th<br>7.54E+4 Y        | 231Th<br>25.52 H           | 232Th<br>1.40E10 Y<br>100%<br>α: 100.00%<br>sF: 1.1E-9% | 233Th<br>1.83 M        | 234Th<br>24.10 D          | 235Th<br>7.2 M           | 236Th<br>37.3 M          | 237Th<br>4.7E10 Y          |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%          | α: 100.00%               | α: 100.00%<br>ε≈ 0.01%   | α: 100.00%               | α: 100.00%                | α: 100.00%                | α: 100.00%                | α: 100.00%<br>ε: 2.0E-7% | α: 100.00%                 | α: 100.00%                | α: 100.00%             | α: 100.00%                | α: 100.00%                 | α≈ 90.00%<br>ε≈ 10.00%     | α: 100.00%              | α: 100.00%                 | α: 100.00%               | α: 100.00%<br>200: 1E-11% | α: 100.00%<br>24Ne≈ 6E-11% | β-: 100.00%<br>α≈ 4E-11%                                | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%                   | β-: 100.00%                  | β-: 100.00%                  |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 213Ac<br>738 MS          | 214Ac<br>8.2 S           | 215Ac<br>0.17 S          | 216Ac<br>440 μS           | 217Ac<br>69 NS            | 218Ac<br>1.08 μS          | 219Ac<br>11.8 μS         | 220Ac<br>26.4 MS           | 221Ac<br>52 MS            | 222Ac<br>5.0 S         | 223Ac<br>2.10 M           | 224Ac<br>2.78 H            | 225Ac<br>10.0 D            | 226Ac<br>29.37 H        | 227Ac<br>21.772 Y          | 228Ac<br>6.15 H          | 229Ac<br>62.7 M           | 230Ac<br>122 S             | 231Ac<br>7.5 M                                          | 232Ac<br>119 S         | 233Ac<br>145 S            | 234Ac<br>44 S            | 235Ac<br>≈40 S           | 236Ac<br>≈2E10 Y           |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | α≤ 100.00%               | α≥ 89.00%<br>ε≤ 11.00%   | α: 99.91%<br>ε: 0.09%    | α: 100.00%                | α≈ 100.00%<br>ε≤ 2.00%    | α: 100.00%                | α: 100.00%               | α: 100.00%<br>ε: 5.0E-4%   | α: 100.00%                | α: 99.00%<br>ε: 1.00%  | α: 99.00%<br>ε: 1.00%     | ε: 90.90%<br>α: 9.10%      | α: 100.00%<br>14C: 5E-10%  | β-: 83.00%<br>ε: 17.00% | β-: 98.62%<br>α: 1.38%     | β-: 100.00%              | β-: 100.00%               | β-: 100.00%                | β-: 100.00%                                             | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%                   | β-: 100.00%                  | β-: 100.00%                  |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 212Ra<br>13.0 S          | 213Ra<br>2.73 M          | 214Ra<br>2.46 S          | 215Ra<br>1.55 MS          | 216Ra<br>182 NS           | 217Ra<br>1.6 μS           | 218Ra<br>25.2 μS         | 219Ra<br>10 MS             | 220Ra<br>18 MS            | 221Ra<br>28 S          | 222Ra<br>38.0 S           | 223Ra<br>11.43 D           | 224Ra<br>3.6319 D          | 225Ra<br>14.9 D         | 226Ra<br>1600 Y            | 227Ra<br>42.2 M          | 228Ra<br>5.75 Y           | 229Ra<br>4.0 M             | 230Ra<br>93 M                                           | 231Ra<br>103 S         | 232Ra<br>4.2 M            | 233Ra<br>30 S            | 234Ra<br>30 S            |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | α≈ 85.00%<br>ε≈ 15.00%   | α: 80.00%<br>ε: 20.00%   | α: 99.94%<br>ε: 0.06%    | α: 100.00%                | α: 100.00%<br>ε < 1.0E-8% | α≈ 100.00%                | α: 100.00%               | α: 100.00%                 | α: 100.00%                | α: 100.00%             | α: 100.00%<br>14C: 1E-12% | α: 100.00%<br>14C: 8.9E-8% | α: 100.00%<br>14C: 4.0E-9% | β-: 100.00%             | α: 100.00%<br>14C: 3.2E-9% | β-: 100.00%              | β-: 100.00%               | β-: 100.00%                | β-: 100.00%                                             | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%                   | β-: 100.00%                  | β-: 100.00%                  |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 211Fr<br>3.10 M          | 212Fr<br>20.0 M          | 213Fr<br>34.82 S         | 214Fr<br>5.0 MS           | 215Fr<br>86 NS            | 216Fr<br>0.70 μS          | 217Fr<br>19 μS           | 218Fr<br>1.0 MS            | 219Fr<br>20 MS            | 220Fr<br>27.4 S        | 221Fr<br>4.9 M            | 222Fr<br>14.2 M            | 223Fr<br>22.00 M           | 224Fr<br>3.33 M         | 225Fr<br>3.95 M            | 226Fr<br>49 S            | 227Fr<br>2.47 M           | 228Fr<br>38 S              | 229Fr<br>50.2 S                                         | 230Fr<br>19.1 S        | 231Fr<br>17.6 S           | 232Fr<br>5.5 S           |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | α > 80.00%<br>ε < 20.00% | ε: 57.00%<br>α: 43.00%   | α: 99.44%<br>ε: 0.56%    | α: 100.00%                | α: 100.00%                | α: 100.00%<br>ε < 2.0E-7% | α: 100.00%               | α: 100.00%                 | α: 100.00%                | α: 99.65%<br>β-: 0.35% | α: 100.00%<br>β- < 0.10%  | β-: 100.00%                | β-: 99.99%<br>α: 6.0E-3%   | β-: 100.00%             | β-: 100.00%                | β-: 100.00%              | β-: 100.00%               | β-: 100.00%                | β-: 100.00%                                             | β-: 100.00%            | β-: 100.00%               | β-: 100.00%              | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%                   | β-: 100.00%                  | β-: 100.00%                  |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 210Rn<br>2.4 H           | 211Rn<br>14.6 H          | 212Rn<br>23.9 M          | 213Rn<br>19.5 MS          | 214Rn<br>0.27 μS          | 215Rn<br>2.30 μS          | 216Rn<br>45 μS           | 217Rn<br>0.54 MS           | 218Rn<br>35 MS            | 219Rn<br>3.96 S        | 220Rn<br>55.6 S           | 221Rn<br>25 M              | 222Rn<br>3.8235 D          | 223Rn<br>24.3 M         | 224Rn<br>107 M             | 225Rn<br>4.66 M          | 226Rn<br>7.4 M            | 227Rn<br>20.8 S            | 228Rn<br>65 S                                           |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | α: 96.00%<br>ε: 4.00%    | ε: 72.60%<br>α: 27.40%   | α: 100.00%               | α: 100.00%                | α: 100.00%                | α: 100.00%                | α: 100.00%               | α: 100.00%                 | α: 100.00%                | α: 100.00%             | α: 100.00%                | β-: 78.00%<br>α: 22.00%    | α: 100.00%                 | β-: 100.00%             | β-: 100.00%                | β-: 100.00%              | β-: 100.00%               | β-: 100.00%                | β-: 100.00%                                             |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 209At<br>5.41 H          | 210At<br>8.1 H           | 211At<br>7.214 H         | 212At<br>0.314 S          | 213At<br>125 NS           | 214At<br>558 NS           | 215At<br>0.10 MS         | 216At<br>0.30 MS           | 217At<br>32.3 MS          | 218At<br>1.5 S         | 219At<br>56 S             | 220At<br>3.71 M            | 221At<br>2.3 M             | 222At<br>54 S           | 223At<br>50 S              |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | ε: 95.90%<br>α: 4.10%    | ε: 99.82%<br>α: 0.18%    | ε: 58.20%<br>α: 41.80%   | α: 100.00%<br>ε < 0.03%   | α: 100.00%                | α: 100.00%                | α: 100.00%               | α: 100.00%<br>β- < 6.0E-3% | α: 99.99%<br>β-: 7.0E-3%  | α: 99.90%<br>β-: 0.10% | α≈ 97.00%<br>β≈ 3.00%     | β-: 92.00%<br>α: 8.00%     | β-: 100.00%                | β-: 100.00%             | β-: 100.00%                |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 208Po<br>2.898 Y         | 209Po<br>102 Y           | 210Po<br>138.376 D       | 211Po<br>0.516 S          | 212Po<br>0.299 μS         | 213Po<br>3.72 μS          | 214Po<br>164.3 μS        | 215Po<br>1.781 MS          | 216Po<br>0.145 S          | 217Po<br>1.53 S        | 218Po<br>3.098 M          | 219Po<br>≈2 M              | 220Po<br>>300 NS           |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | α: 100.00%<br>ε: 4.0E-3% | α: 99.52%<br>ε: 0.48%    | α: 100.00%               | α: 100.00%                | α: 100.00%                | α: 100.00%                | α: 100.00%               | α: 100.00%                 | α: 100.00%<br>β-: 2.3E-4% | α                      | α: 99.98%<br>β-: 0.02%    | β-<br>α                    | β-<br>α                    |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 207Bi<br>32.9 Y          | 208Bi<br>3.68E+5 Y       | 209Bi<br>STABLE<br>100%  | 210Bi<br>5.012 D          | 211Bi<br>2.14 M           | 212Bi<br>60.55 M          | 213Bi<br>45.59 M         | 214Bi<br>19.9 M            | 215Bi<br>7.6 M            | 216Bi<br>2.25 S        | 217Bi<br>98.5 S           | 218Bi<br>33 S              |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | ε: 100.00%               | ε: 100.00%               |                          | β-: 100.00%<br>α: 1.3E-4% | α: 99.72%<br>β-: 0.28%    | β-: 64.06%<br>α: 35.94%   | β-: 97.80%<br>α: 2.20%   | β-: 99.98%<br>α: 0.02%     | β-: 100.00%               | β-≤ 100.00%            | β-: 100.00%               | β-: 100.00%                |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 206Pb<br>STABLE<br>24.1% | 207Pb<br>STABLE<br>22.1% | 208Pb<br>STABLE<br>52.4% | 209Pb<br>3.253 H          | 210Pb<br>22.20 Y          | 211Pb<br>36.1 M           | 212Pb<br>10.64 H         | 213Pb<br>10.2 M            | 214Pb<br>26.8 M           | 215Pb<br>36 S          |                           |                            |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% |                          |                          |                          | β-: 100.00%               | β-: 100.00%<br>α: 1.9E-6% | β-: 100.00%               | β-: 100.00%              | β-: 100.00%                | β-: 100.00%               | β-: 100.00%            | β-: 100.00%               |                            |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |
| α: 100.00%<br>β: 0% | 205Tl<br>STABLE          | 206Tl<br>4.200 M         | 207Tl<br>4.77 M          | 208Tl<br>3.053 M          | 209Tl<br>2.161 M          | 210Tl<br>1.30 M           | 211Tl<br>>300 NS         | 212Tl<br>>300 NS           |                           |                        |                           |                            |                            |                         |                            |                          |                           |                            |                                                         |                        |                           |                          |                          |                            |                           |                               |                              |                              |                |                                                            |                   |

中性子数

ブルックヘブンの核図表より抜粋したウラン238・トリウム232の壊変系列

<http://www.nndc.bnl.gov/chart/>

右上の赤丸で示した<sup>238</sup>U、<sup>232</sup>Thは地球誕生以前に生成したもので、鉱物中に広く存在します。  
これら2種類の同位体を始点として、どのように壊変が進むかを辿ってみて下さい。

正しく辿れるとウラン系列は<sup>206</sup>Pb、トリウム系列は<sup>208</sup>Pbに到着します。  
また、途中でラジウム、ポロニウム、ラドンなど、著名な元素が登場するはずです。

|                                                            |
|------------------------------------------------------------|
| 238U<br>4.468E9 Y<br>99.2742%<br>α: 100.00%<br>sF: 5.5E-5% |
|------------------------------------------------------------|

- 背景の色：壊変モード
- 黄色：α壊変＝陽子数－2、中性子数－2
  - 赤色：β壊変＝陽子数＋1、中性子数－1
  - 青色：β＋/EC壊変＝陽子数－1、中性子数＋1

- 2行目の数字：半減期  
3行目の数字：天然存在比  
4/5行目の数字：壊変確率（sFは自発核分裂）

※凡例・記載内容は核図表によって異なります。