Física Nuclear

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Aula 2 - Reações Nucleares

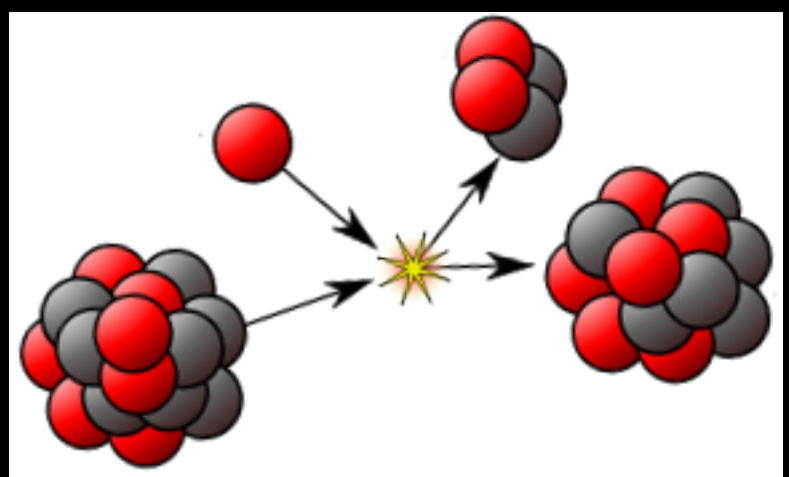
Reações Nucleares

- Reações químicas
- Estrutura atômica
- Reações nucleares
- Decaimento α
- Decaimento β
- $E=mc^2$

Reações nucleares

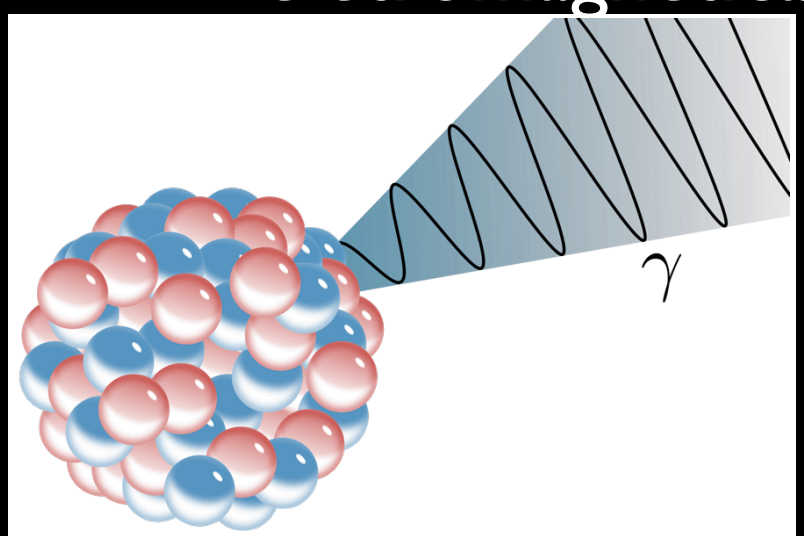
Reação Nuclear

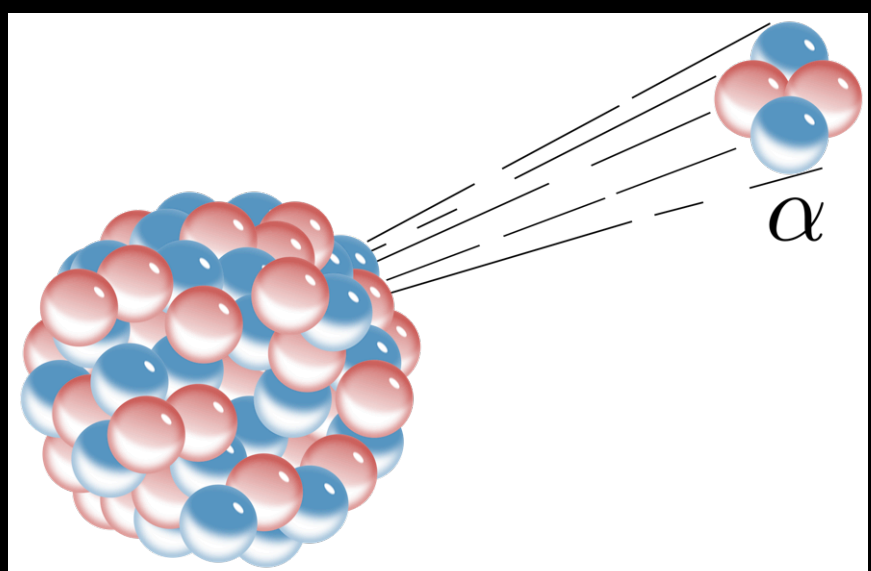
- Altera número de prótons e/ou nêutrons
- Decaimento: 3 modos principais
- Existe um tempo médio para que ocorra
- Alteração do elemento químico



Reação Nuclear

- Decaimento α: emite partícula α (2 prótons e 2 nêutrons)
- $^{218}Po_{84} \rightarrow {}^{4}\alpha_{2} + {}^{214}Pb_{82}$
- Decaimento γ: núcleo relaxa para um estado menos energético emitindo onda eletromagnética



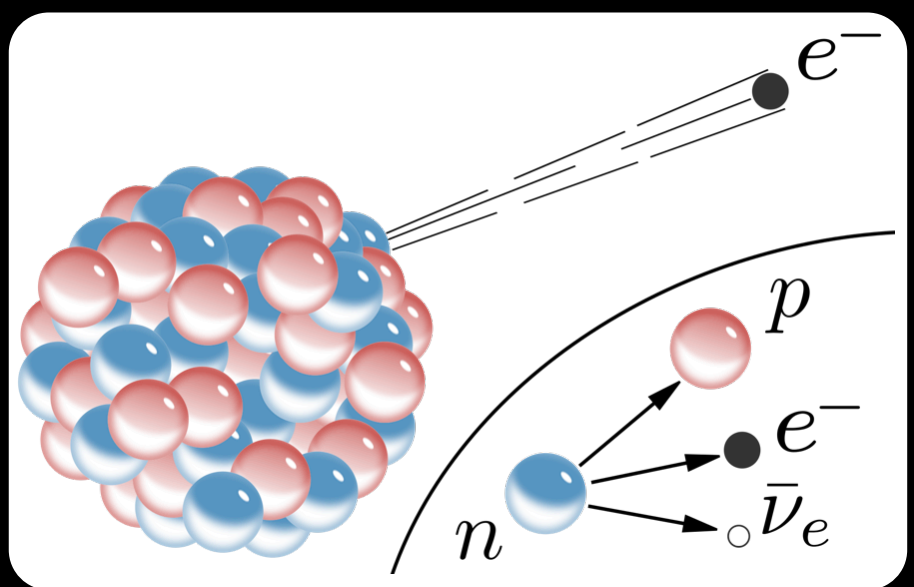


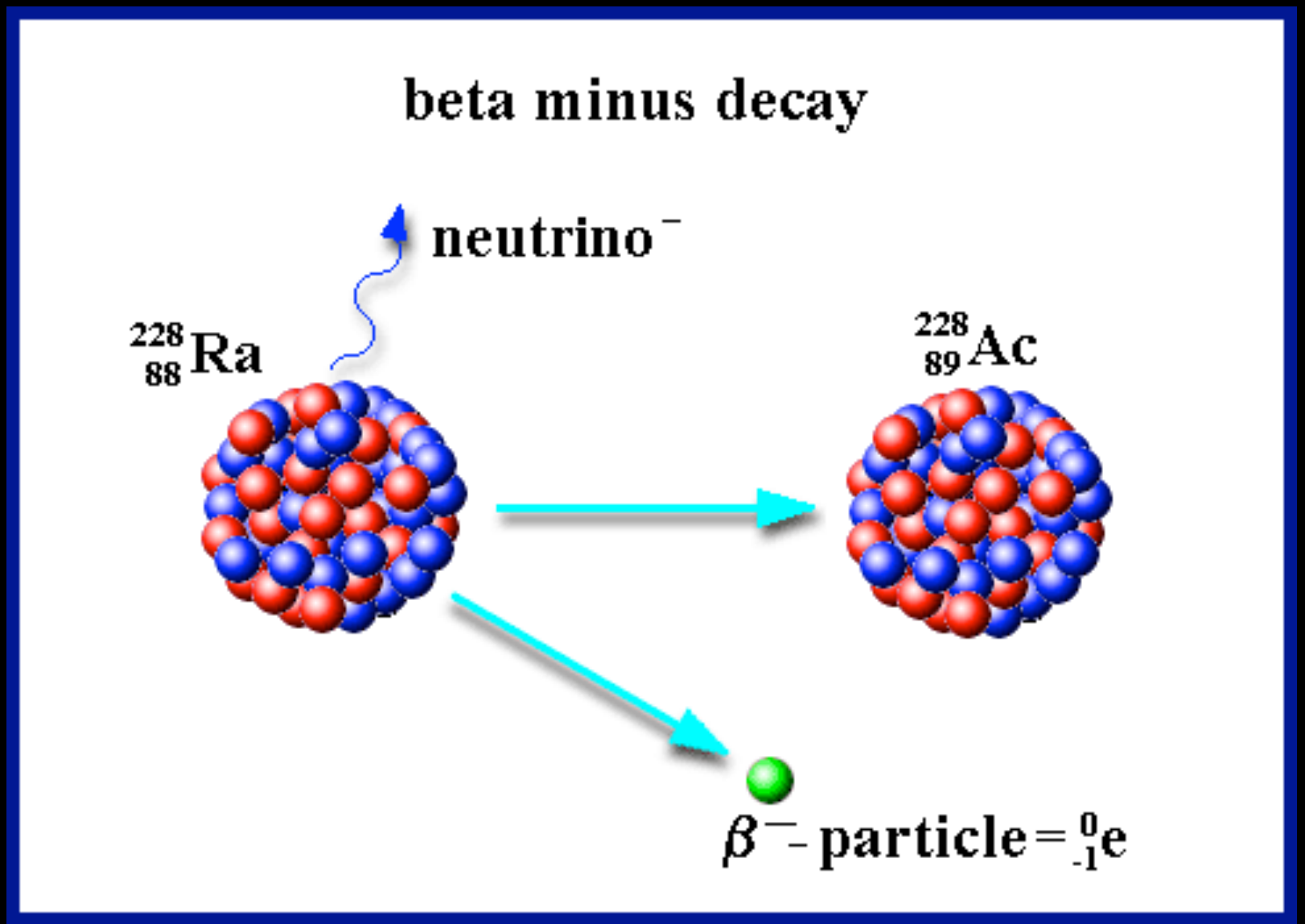
Reação Nuclear

- Animação

Reação Nuclear

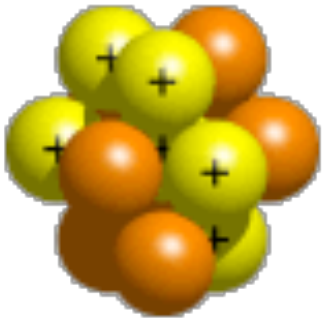
- Decaimento β^-: um nêutron se converte em um próton mais uma partícula β^- (elétron + neutrino), que é emitida do núcleo.
- Decaimento β^+: um próton se converte em um nêutron mais uma partícula β^+ (pósitron + neutrino)




beta minus decay
neutrino⁻
$^{228}_{88}$Ra
$^{228}_{89}$Ac
β^- - particle = $^{0}_{-1}$e

Beta-minus Decay

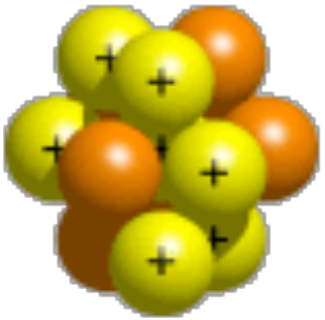
Carbon-14



6 protons
8 neutrons

β^-

Nitrogen-14

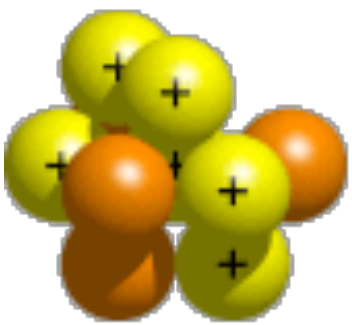


7 protons
7 neutrons

+ **Antineutrino** $\bar{\nu}$ + **Electron** -

Beta-plus Decay

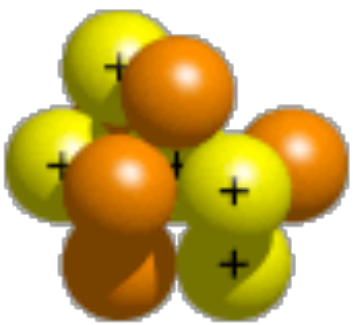
Carbon-10



6 protons
4 neutrons

β^+

Boron-10

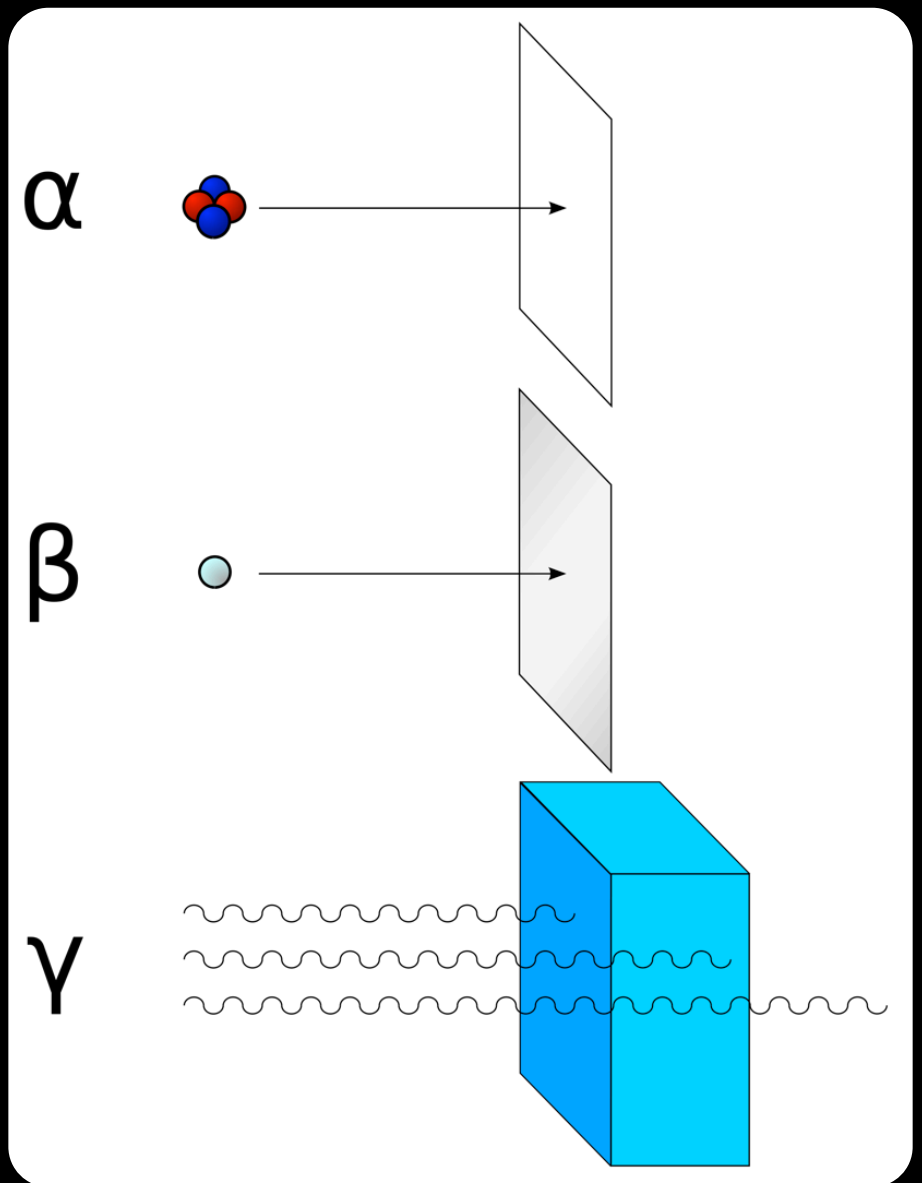


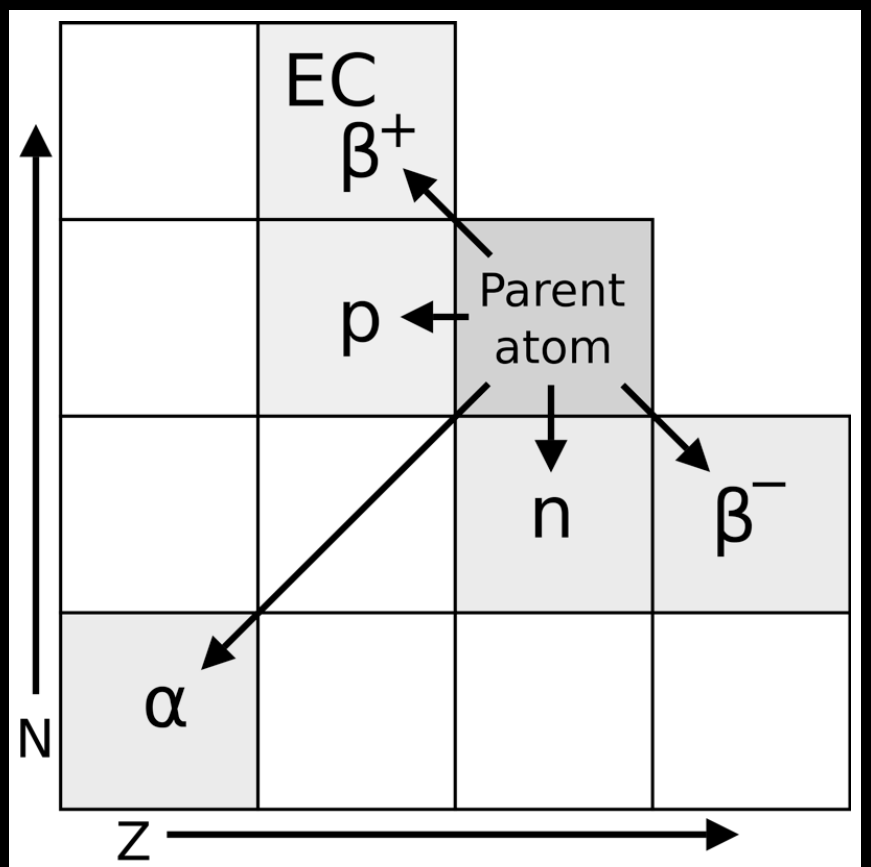
5 protons
5 neutrons

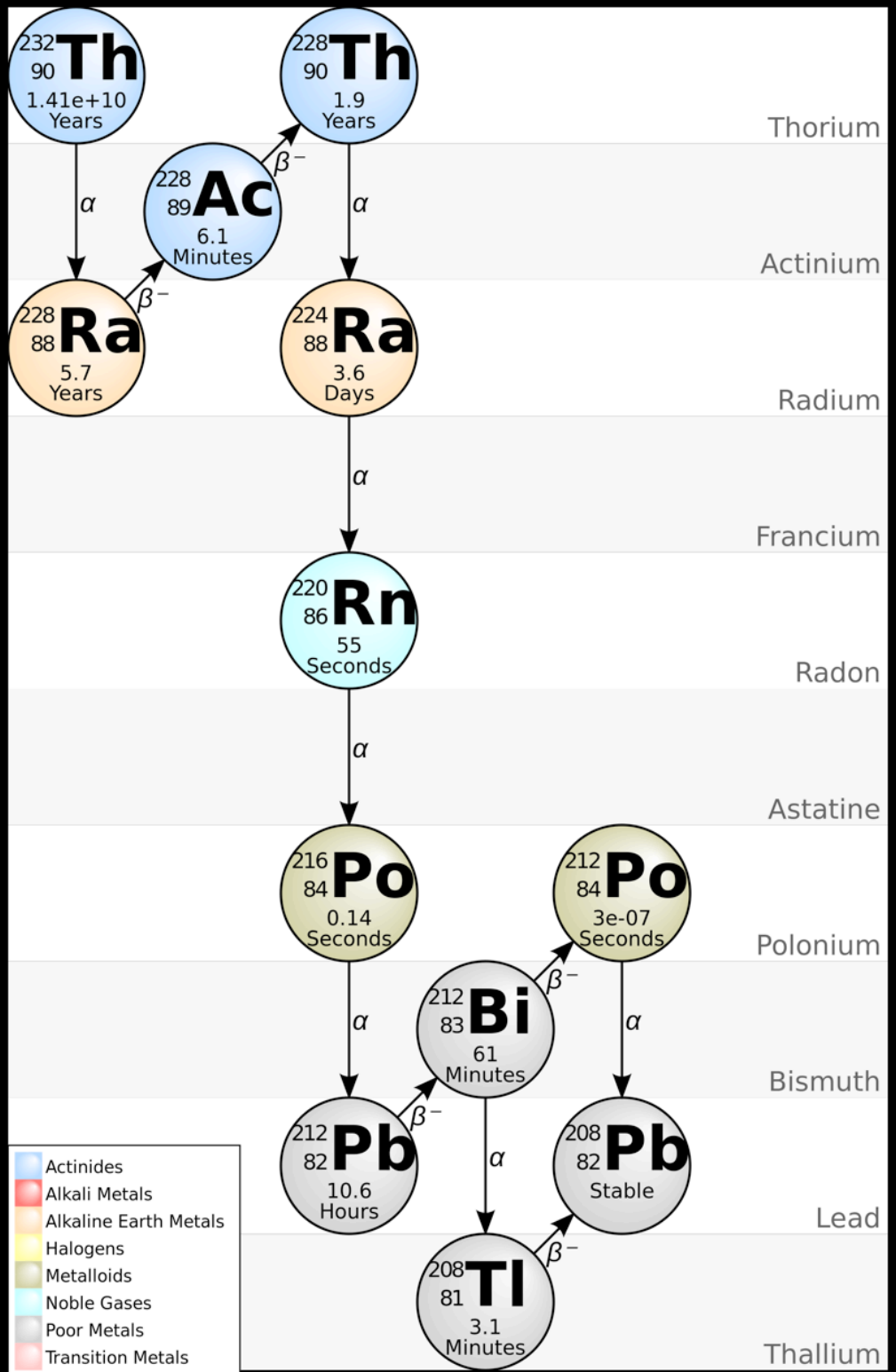
+ **Neutrino** ν + **Positron** +

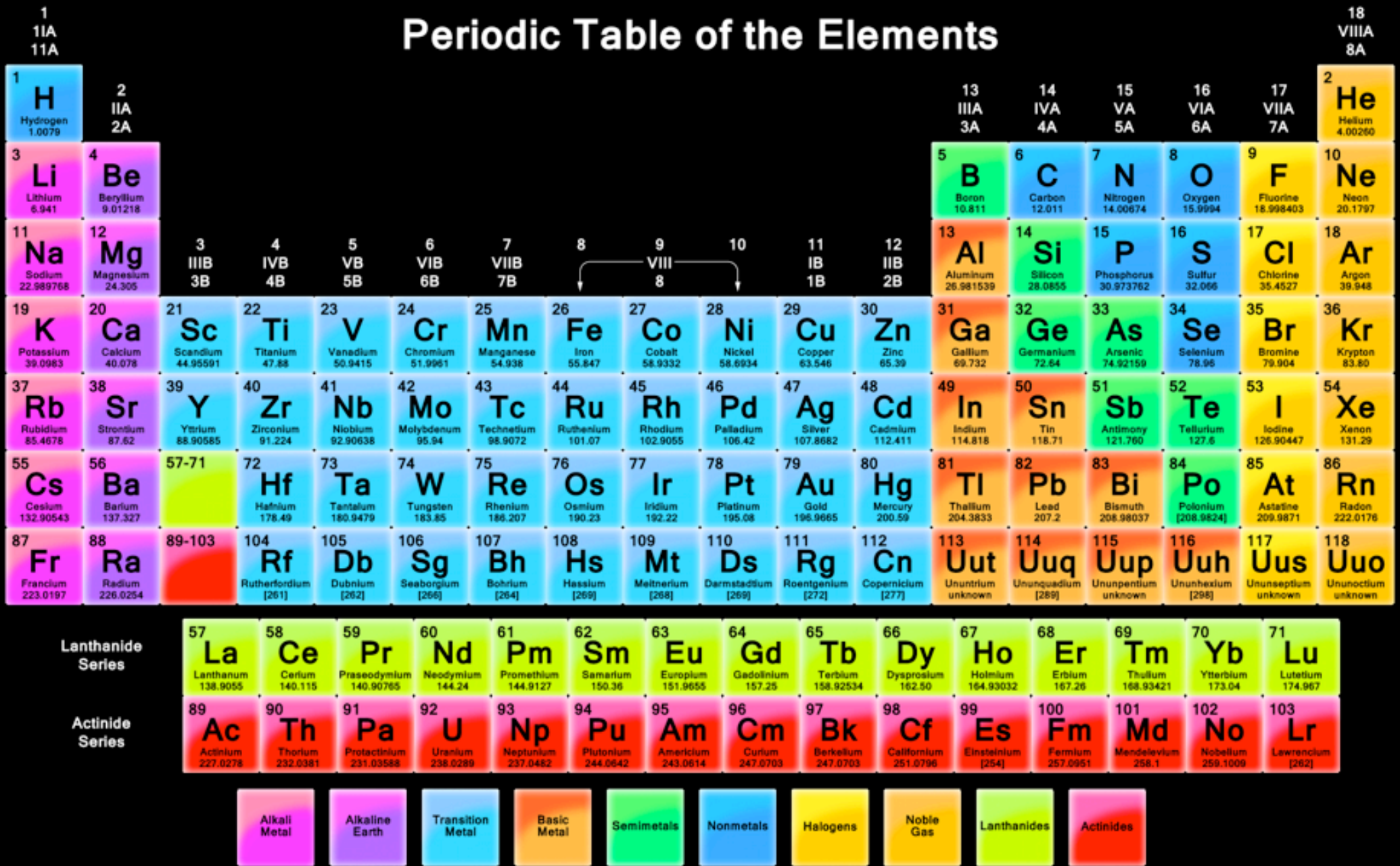
Reação Nuclear

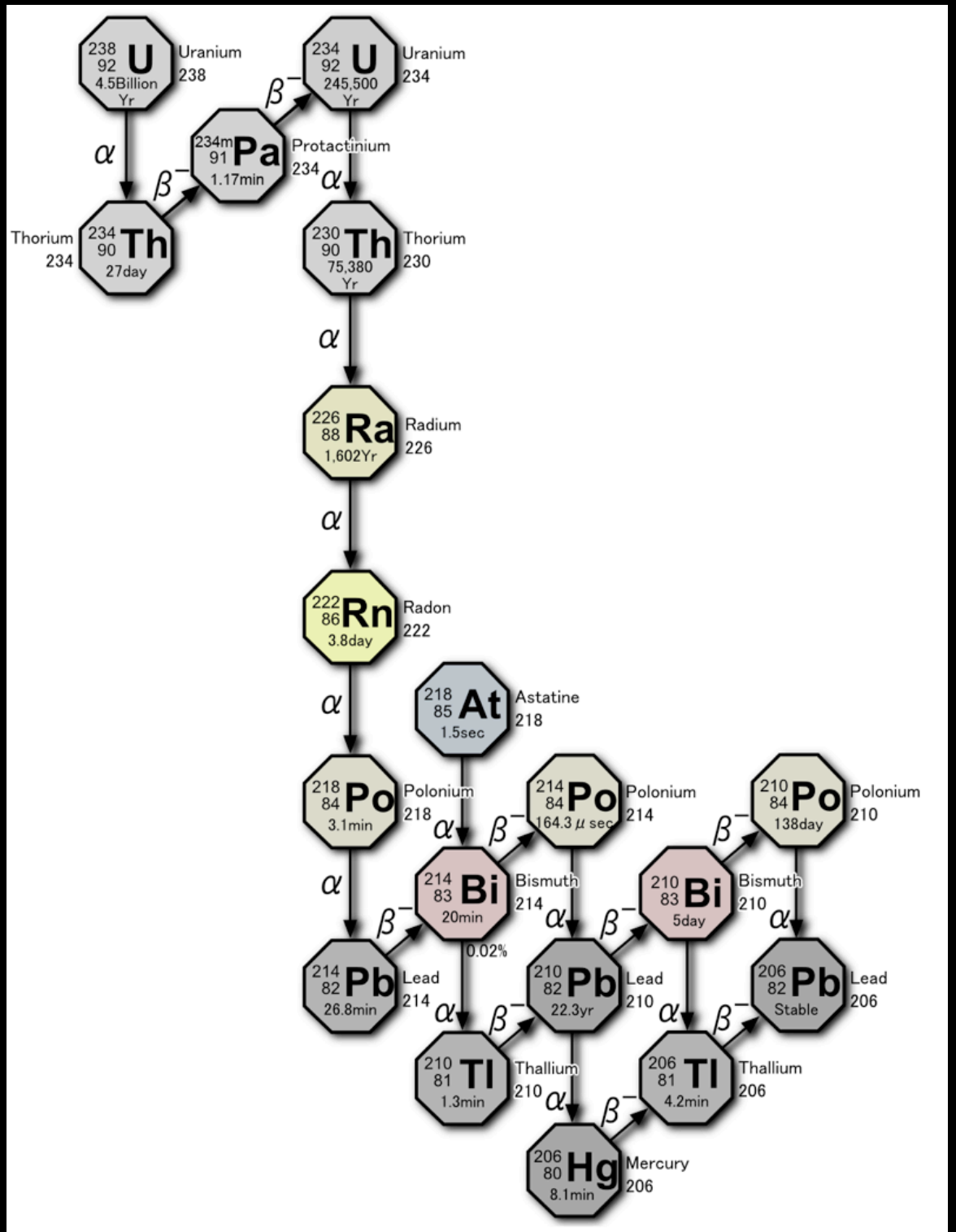
- Animação

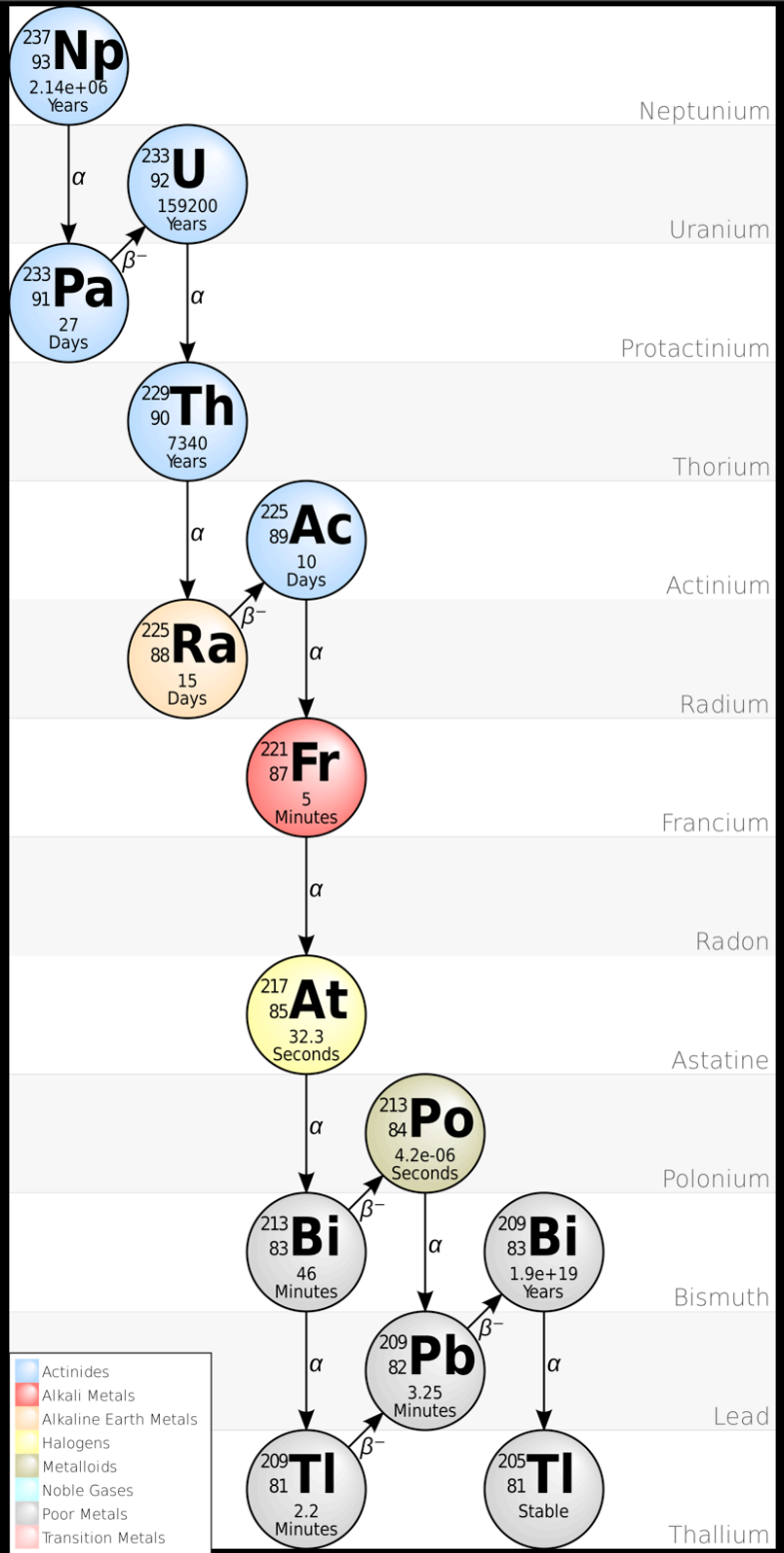

α
β
γ

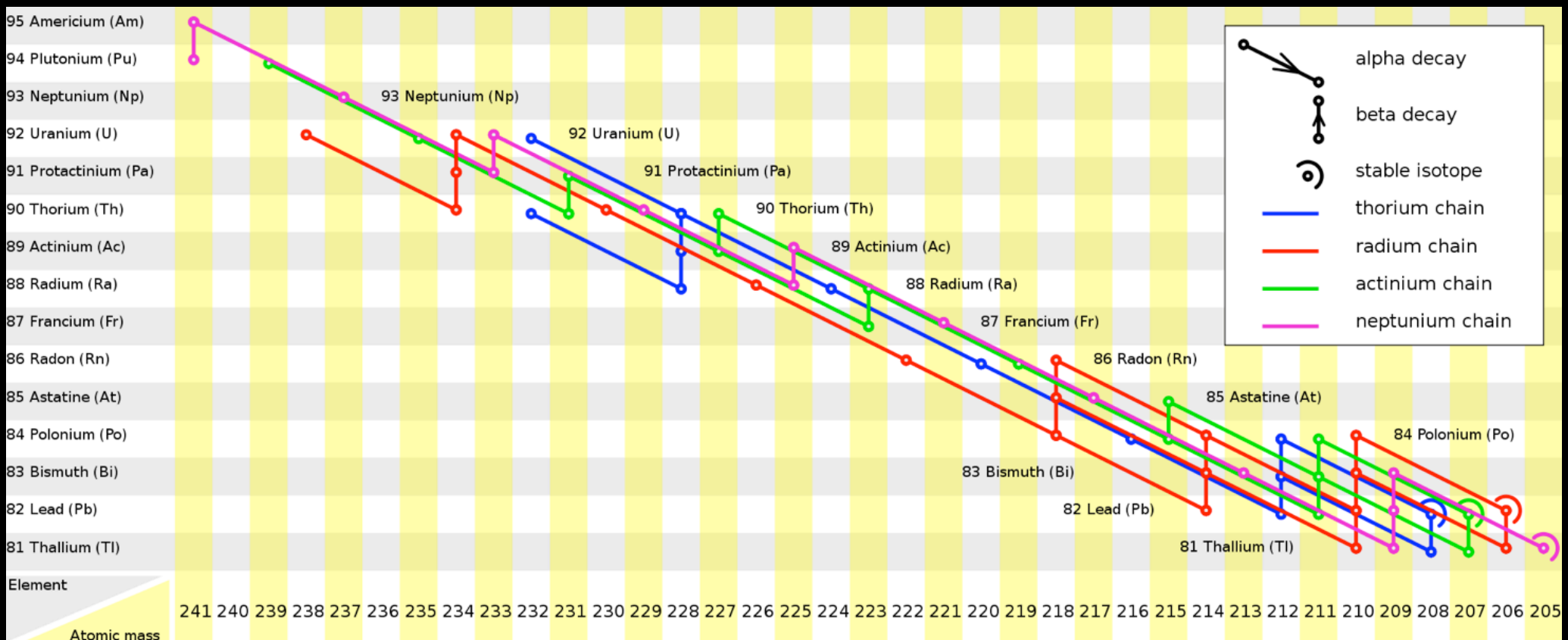

EC
β+
p
Parent
atom
n
β−
α
N
Z

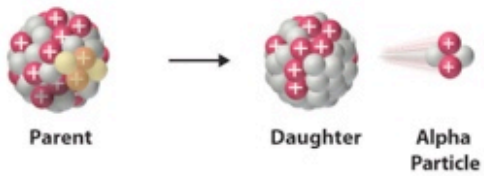
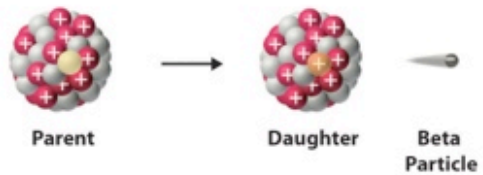
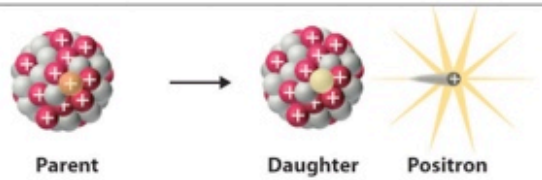
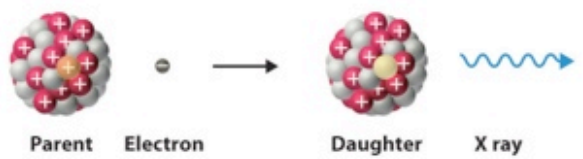
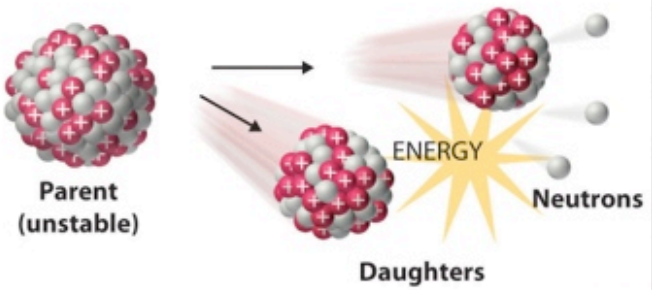

232 90 Th 1.41e+10 Years
228 90 Th 1.9 Years
228 89 Ac 6.1 Minutes
228 88 Ra 5.7 Years
224 88 Ra 3.6 Days
220 86 Rn 55 Seconds
216 84 Po 0.14 Seconds
212 84 Po 3e-07 Seconds
212 83 Bi 61 Minutes
212 82 Pb 10.6 Hours
208 82 Pb Stable
208 81 Tl 3.1 Minutes
α
β−
Thorium
Actinium
Radium
Francium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Actinides
Alkali Metals
Alkaline Earth Metals
Halogens
Metalloids
Noble Gases
Poor Metals
Transition Metals

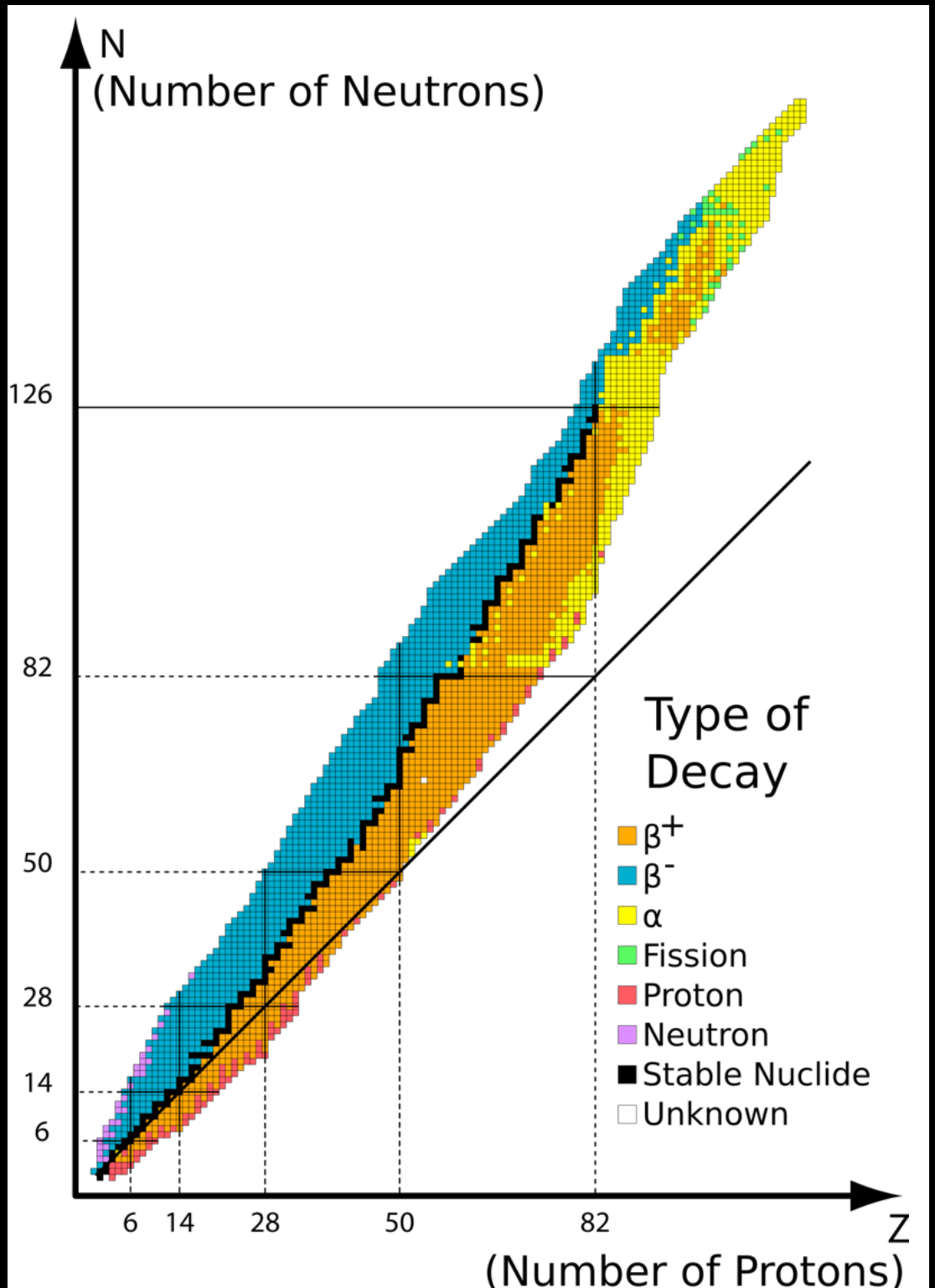

Periodic Table of the Elements
1 1IA 11A
2 IIA 2A
3 IIIB 3B
4 IVB 4B
5 VB 5B
6 VIB 6B
7 VIIB 7B
8 9 VIII 8 10
11 IB 1B
12 IIB 2B
13 IIIA 3A
14 IVA 4A
15 VA 5A
16 VIA 6A
17 VIIA 7A
18 VIIIA 8A
1 H Hydrogen 1.0079
2 He Helium 4.00260
3 Li Lithium 6.941
4 Be Beryllium 9.01218
5 B Boron 10.811
6 C Carbon 12.011
7 N Nitrogen 14.00674
8 O Oxygen 15.9994
9 F Fluorine 18.998403
10 Ne Neon 20.1797
11 Na Sodium 22.989768
12 Mg Magnesium 24.305
13 Al Aluminum 26.981539
14 Si Silicon 28.0855
15 P Phosphorus 30.973762
16 S Sulfur 32.066
17 Cl Chlorine 35.4527
18 Ar Argon 39.948
19 K Potassium 39.0983
20 Ca Calcium 40.078
21 Sc Scandium 44.95591
22 Ti Titanium 47.88
23 V Vanadium 50.9415
24 Cr Chromium 51.9961
25 Mn Manganese 54.938
26 Fe Iron 55.847
27 Co Cobalt 58.9332
28 Ni Nickel 58.6934
29 Cu Copper 63.546
30 Zn Zinc 65.39
31 Ga Gallium 69.732
32 Ge Germanium 72.64
33 As Arsenic 74.92159
34 Se Selenium 78.96
35 Br Bromine 79.904
36 Kr Krypton 83.80
37 Rb Rubidium 85.4678
38 Sr Strontium 87.62
39 Y Yttrium 88.90585
40 Zr Zirconium 91.224
41 Nb Niobium 92.90638
42 Mo Molybdenum 95.94
43 Tc Technetium 98.9072
44 Ru Ruthenium 101.07
45 Rh Rhodium 102.9055
46 Pd Palladium 106.42
47 Ag Silver 107.8682
48 Cd Cadmium 112.411
49 In Indium 114.818
50 Sn Tin 118.71
51 Sb Antimony 121.760
52 Te Tellurium 127.6
53 I Iodine 126.90447
54 Xe Xenon 131.29
55 Cs Cesium 132.90543
56 Ba Barium 137.327
57-71
72 Hf Hafnium 178.49
73 Ta Tantalum 180.9479
74 W Tungsten 183.85
75 Re Rhenium 186.207
76 Os Osmium 190.23
77 Ir Iridium 192.22
78 Pt Platinum 195.08
79 Au Gold 196.9665
80 Hg Mercury 200.59
81 Tl Thallium 204.3833
82 Pb Lead 207.2
83 Bi Bismuth 208.98037
84 Po Polonium [208.9824]
85 At Astatine 209.9871
86 Rn Radon 222.0176
87 Fr Francium 223.0197
88 Ra Radium 226.0254
89-103
104 Rf Rutherfordium [261]
105 Db Dubnium [262]
106 Sg Seaborgium [266]
107 Bh Bohrium [264]
108 Hs Hassium [269]
109 Mt Meitnerium [268]
110 Ds Darmstadtium [269]
111 Rg Roentgenium [272]
112 Cn Copernicium [277]
113 Uut Ununtrium unknown
114 Uuq Ununquadium [289]
115 Uup Ununpentium unknown
116 Uuh Ununhexium [298]
117 Uus Ununseptium unknown
118 Uuo Ununoctium unknown
Lanthanide Series
57 La Lanthanum 138.9055
58 Ce Cerium 140.115
59 Pr Praseodymium 140.90765
60 Nd Neodymium 144.24
61 Pm Promethium 144.9127
62 Sm Samarium 150.36
63 Eu Europium 151.9655
64 Gd Gadolinium 157.25
65 Tb Terbium 158.92534
66 Dy Dysprosium 162.50
67 Ho Holmium 164.93032
68 Er Erbium 167.26
69 Tm Thulium 168.93421
70 Yb Ytterbium 173.04
71 Lu Lutetium 174.967
Actinide Series
89 Ac Actinium 227.0278
90 Th Thorium 232.0381
91 Pa Protactinium 231.03588
92 U Uranium 238.0289
93 Np Neptunium 237.0482
94 Pu Plutonium 244.0642
95 Am Americium 243.0614
96 Cm Curium 247.0703
97 Bk Berkelium 247.0703
98 Cf Californium 251.0796
99 Es Einsteinium [254]
100 Fm Fermium 257.0951
101 Md Mendelevium 258.1
102 No Nobelium 259.1009
103 Lr Lawrencium [262]
Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Semimetals
Nonmetals
Halogens
Noble Gas
Lanthanides
Actinides

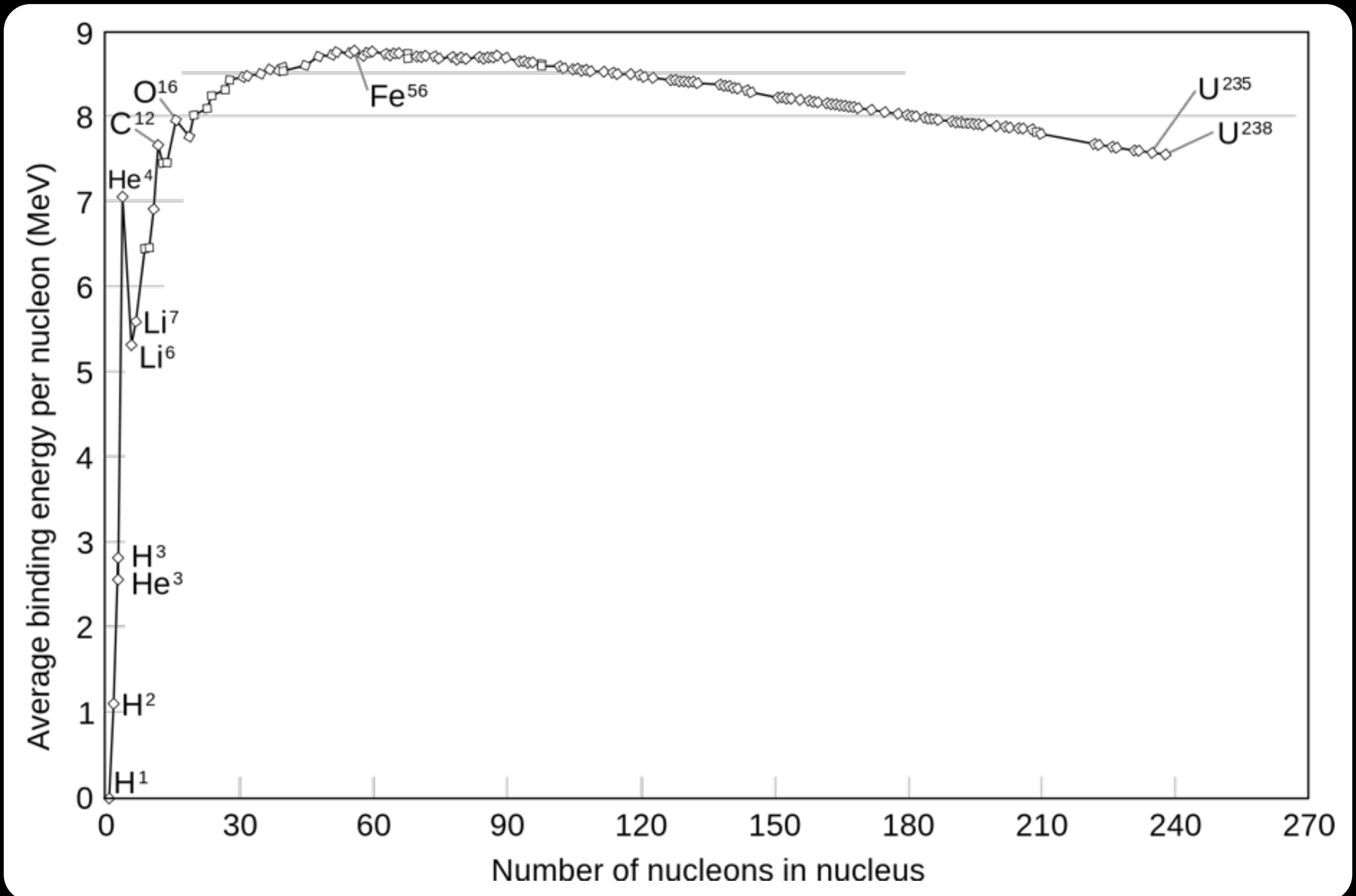

238 92 U 4.5Billion Yr
Uranium 238
234 92 U 245,500 Yr
Uranium 234
234m 91 Pa 1.17min
Protactinium 234
234 90 Th 27day
Thorium 234
230 90 Th 75,380 Yr
Thorium 230
226 88 Ra 1,602Yr
Radium 226
222 86 Rn 3.8day
Radon 222
218 85 At 1.5sec
Astatine 218
218 84 Po 3.1min
Polonium 218
214 84 Po 164.3 μ sec
Polonium 214
210 84 Po 138day
Polonium 210
214 83 Bi 20min
Bismuth 214
210 83 Bi 5day
Bismuth 210
0.02%
214 82 Pb 26.8min
Lead 214
210 82 Pb 22.3yr
Lead 210
206 82 Pb Stable
Lead 206
210 81 Tl 1.3min
Thallium 210
206 81 Tl 4.2min
Thallium 206
206 80 Hg 8.1min
Mercury 206
α
β−

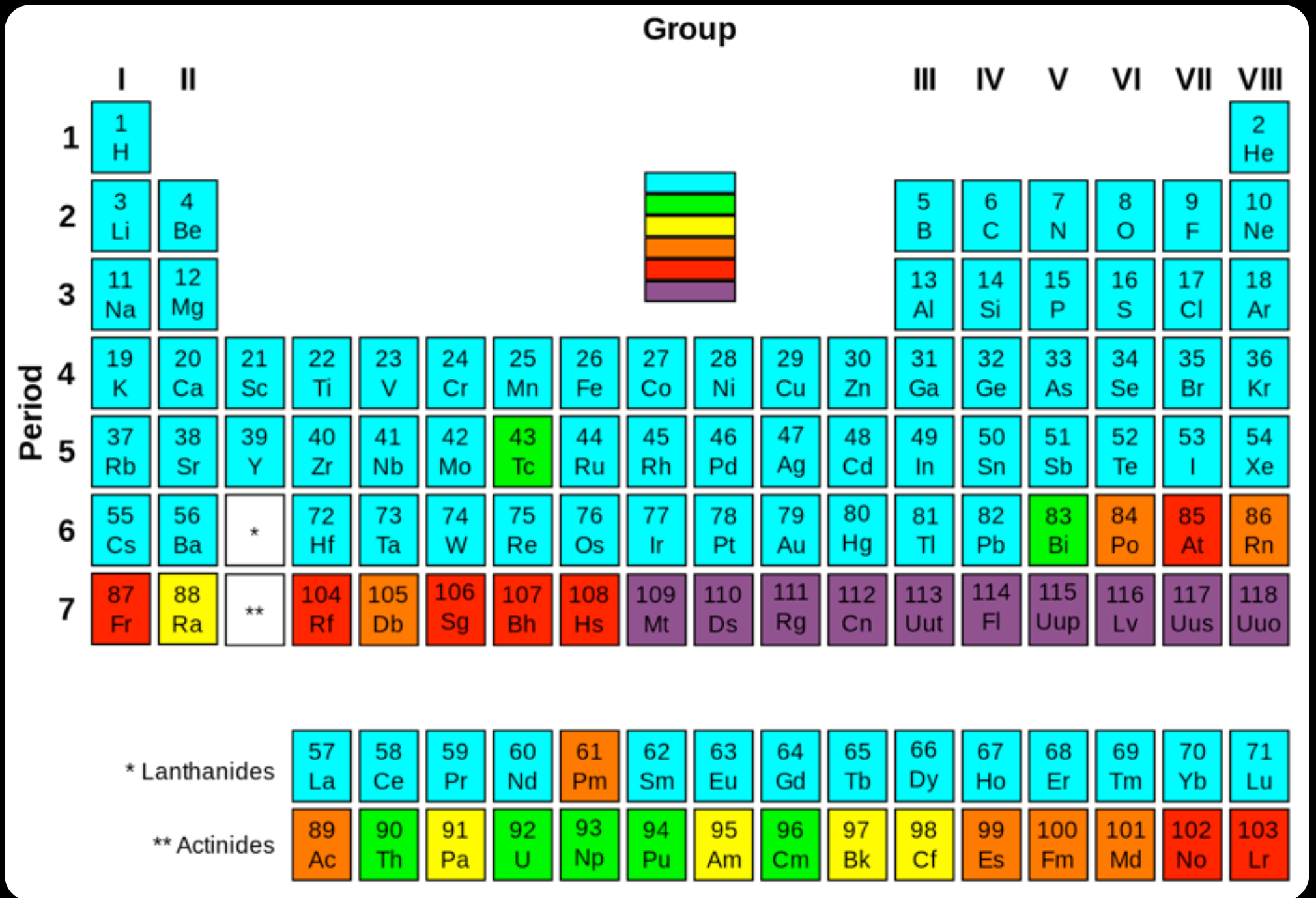

237 93 Np 2.14e+06 Years
Neptunium
α
233 92 U 159200 Years
Uranium
β−
233 91 Pa 27 Days
α
Protactinium
229 90 Th 7340 Years
Thorium
α
225 89 Ac 10 Days
Actinium
β−
225 88 Ra 15 Days
α
Radium
221 87 Fr 5 Minutes
Francium
α
Radon
217 85 At 32.3 Seconds
Astatine
α
213 84 Po 4.2e-06 Seconds
Polonium
β−
213 83 Bi 46 Minutes
α
209 83 Bi 1.9e+19 Years
Bismuth
β−
α
209 82 Pb 3.25 Minutes
α
β−
209 81 Tl 2.2 Minutes
205 81 Tl Stable
Lead
Thallium
Actinides
Alkali Metals
Alkaline Earth Metals
Halogens
Metalloids
Noble Gases
Poor Metals
Transition Metals


95 Americium (Am)
94 Plutonium (Pu)
93 Neptunium (Np)
92 Uranium (U)
91 Protactinium (Pa)
90 Thorium (Th)
89 Actinium (Ac)
88 Radium (Ra)
87 Francium (Fr)
86 Radon (Rn)
85 Astatine (At)
84 Polonium (Po)
83 Bismuth (Bi)
82 Lead (Pb)
81 Thallium (Tl)
Element
Atomic mass
241 240 239 238 237 236 235 234 233 232 231 230 229 228 227 226 225 224 223 222 221 220 219 218 217 216 215 214 213 212 211 210 209 208 207 206 205
alpha decay
beta decay
stable isotope
thorium chain
radium chain
actinium chain
neptunium chain

Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^{4}_{2}\alpha$	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	
Beta decay	${}^{0}_{-1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$	
Positron emission	${}^{0}_{+1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}X' + {}^{0}_{+1}\beta$	
Electron capture	X rays	${}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}X' + X\text{ ray}$	
Gamma emission	${}^{0}_{0}\gamma$	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	
Spontaneous fission	Neutrons	${}^{A+B+C}_{Z+Y}X \longrightarrow {}^{A}_{Z}X' + {}^{B}_{Y}X' + C\,{}^{1}_{0}n$	


N
(Number of Neutrons)
126
82
50
28
14
6
6
14
28
50
82
Z
(Number of Protons)
Type of Decay
β+
β-
α
Fission
Proton
Neutron
Stable Nuclide
Unknown


Average binding energy per nucleon (MeV)
Number of nucleons in nucleus
0
1
2
3
4
5
6
7
8
9
0
30
60
90
120
150
180
210
240
270
H1
H2
H3
He3
He4
Li6
Li7
C12
O16
Fe56
U235
U238


Group
I
II
III
IV
V
VI
VII
VIII
Period
1
2
3
4
5
6
7
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
*
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
**
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110 Ds
111 Rg
112 Cn
113 Uut
114 Fl
115 Uup
116 Lv
117 Uus
118 Uuo
* Lanthanides
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
** Actinides
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

Periodic table with elements colored according to the half-life of their most stable isotope.

Elements which contain at least one stable isotope.

Slightly radioactive elements: the most stable isotope is very long-lived, with a half-life of over four million years.

Significantly radioactive elements: the most stable isotope has half-life between 800 and 34,000 years.

Radioactive elements: the most stable isotope has half-life between one day and 103 years.

Highly radioactive elements: the most stable isotope has half-life between several minutes and one day.

Extremely radioactive elements: the most stable isotope has half-life less than several minutes.