Neutron Activation, Alpha & Beta Decay

as

TRANSMUTATION

of the

ELEMENTS

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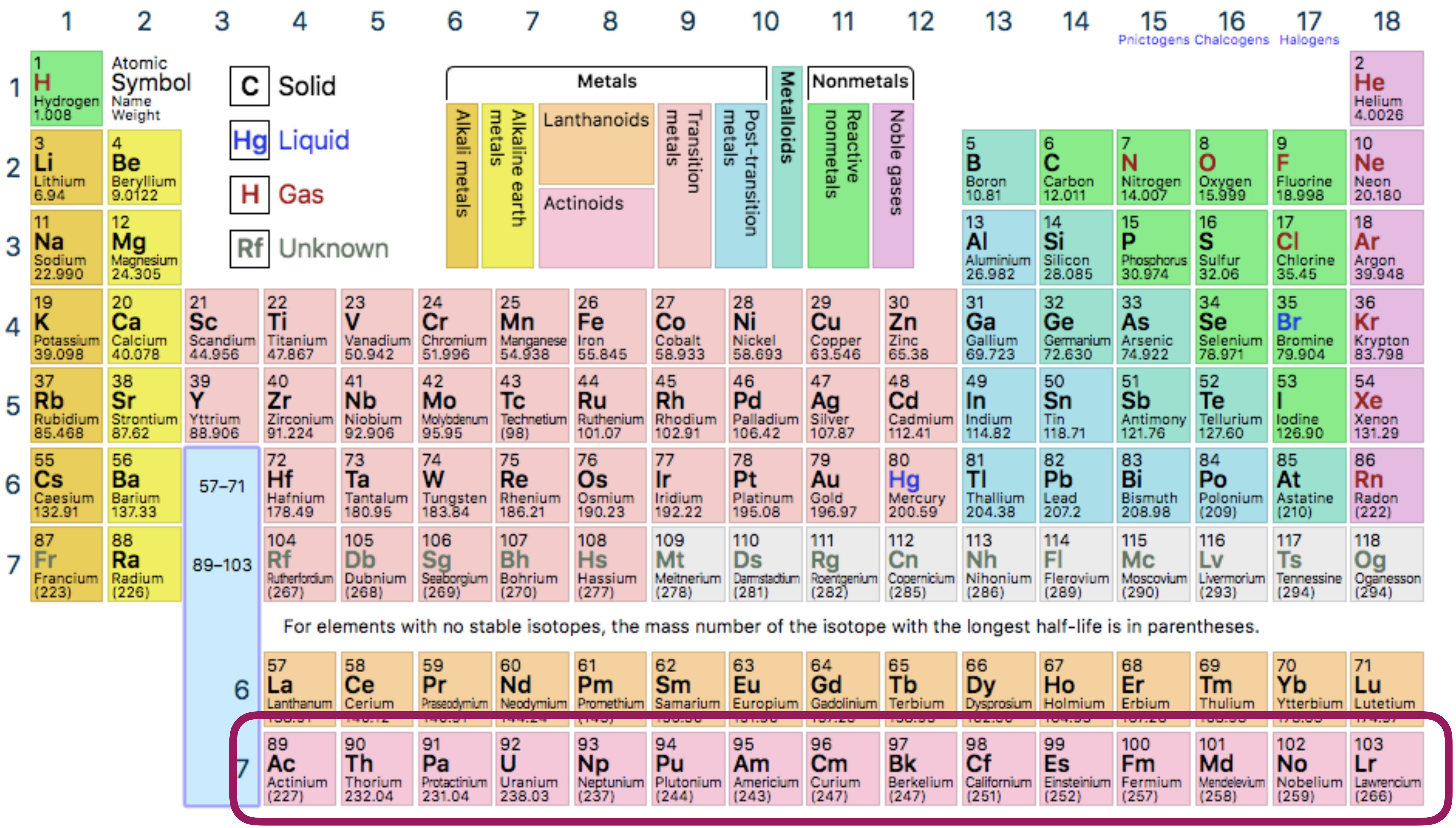
Neutron Decay

$$n \rightarrow p^{+} + e^{-} + \overline{\nu}_{\mathrm{e}}$$

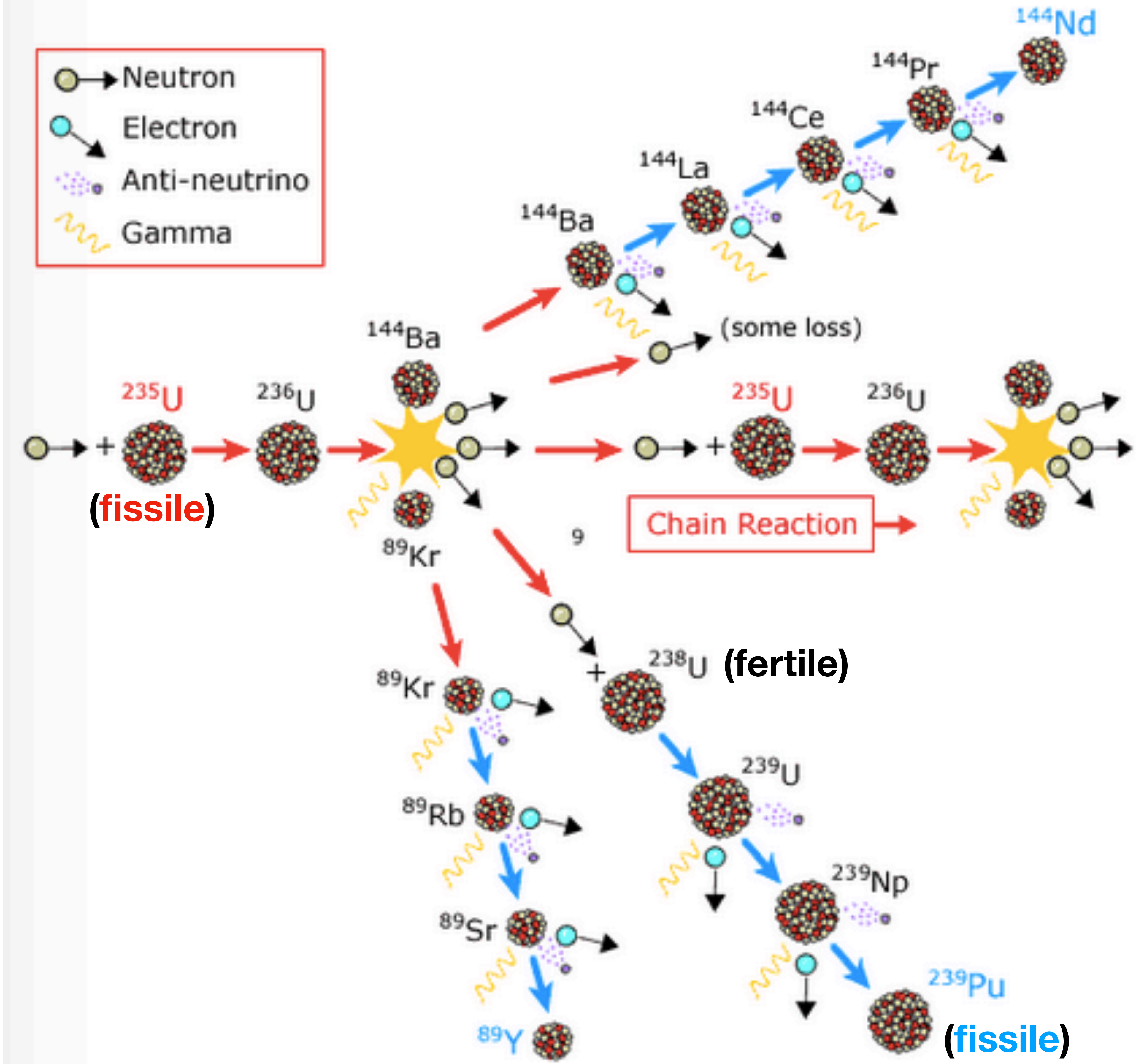
A *free* neutron will β-decay into a proton, an electron and and electron antineutrino in an average of **15 minutes**. When *bound in a nucleus*, neutrons are usually *stable*; but if they are only *weakly* bound, they still may β-decay, leaving behind a nucleus with one extra proton — *i.e.* *transmuted* into a **different element**!

The Periodic Table of the Elements



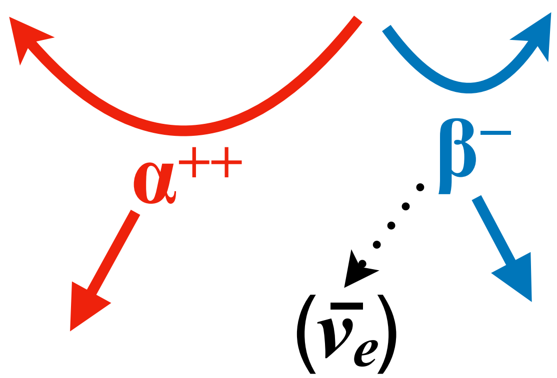
the Actinides

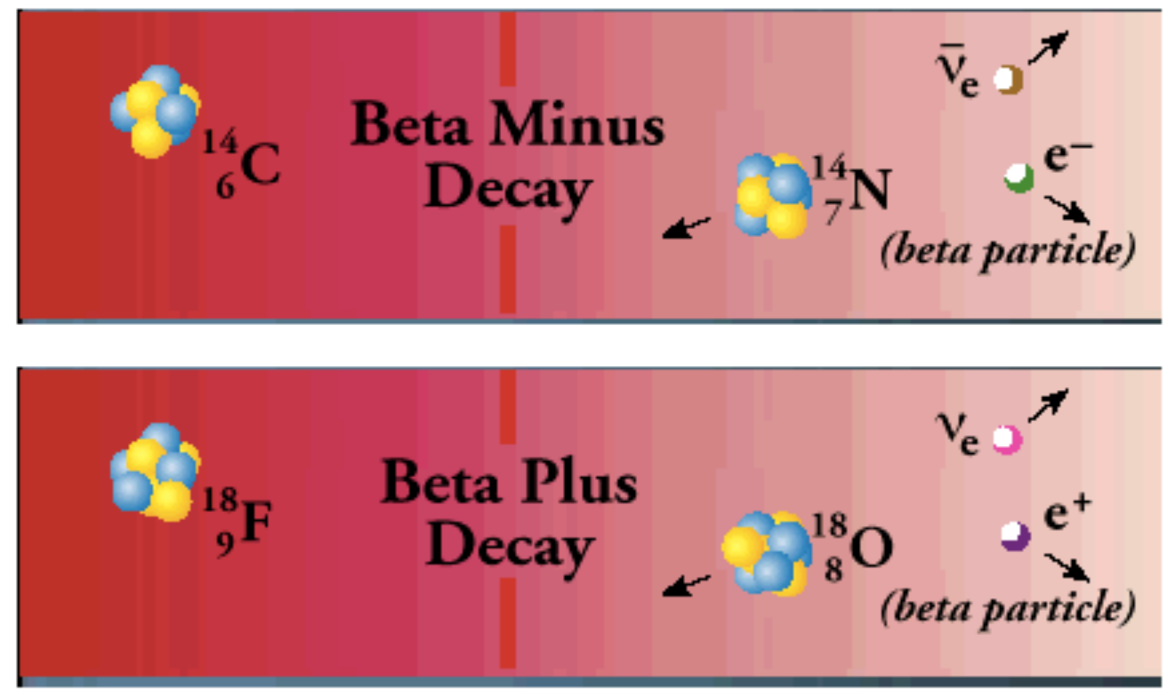
Transmutation tricks with Neutrons:

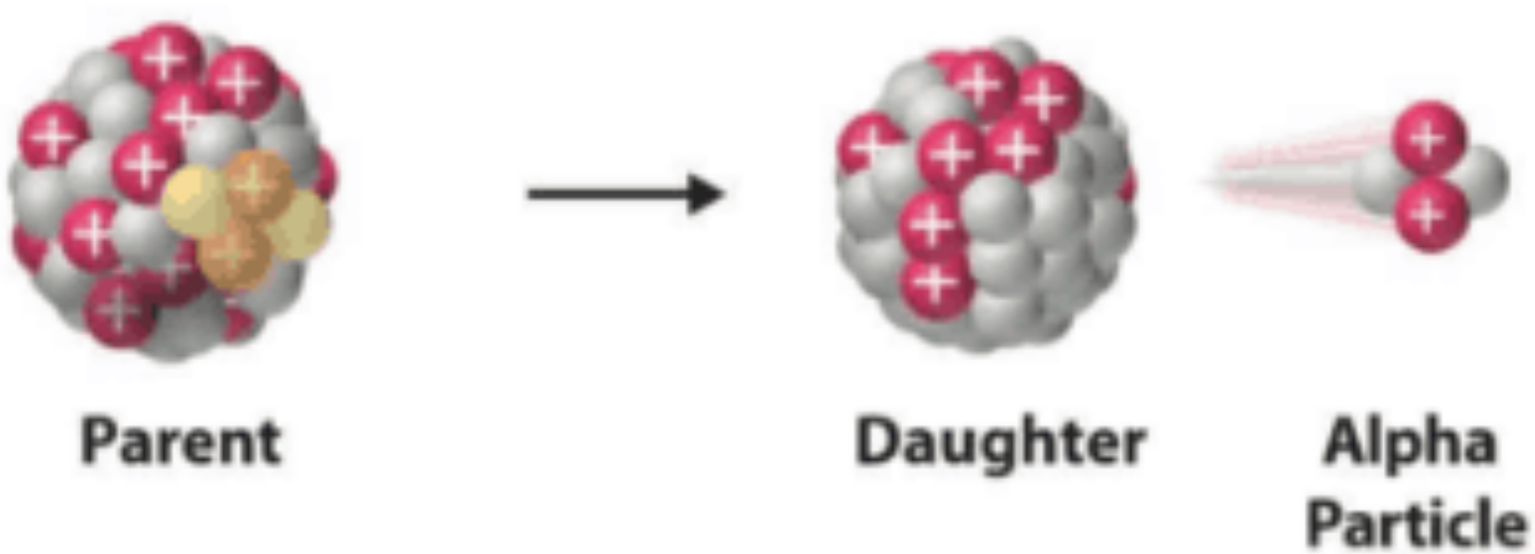


Spontaneous Transmutation among the Actinides

89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium
(227)	232.04	231.04	238.03	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(266)





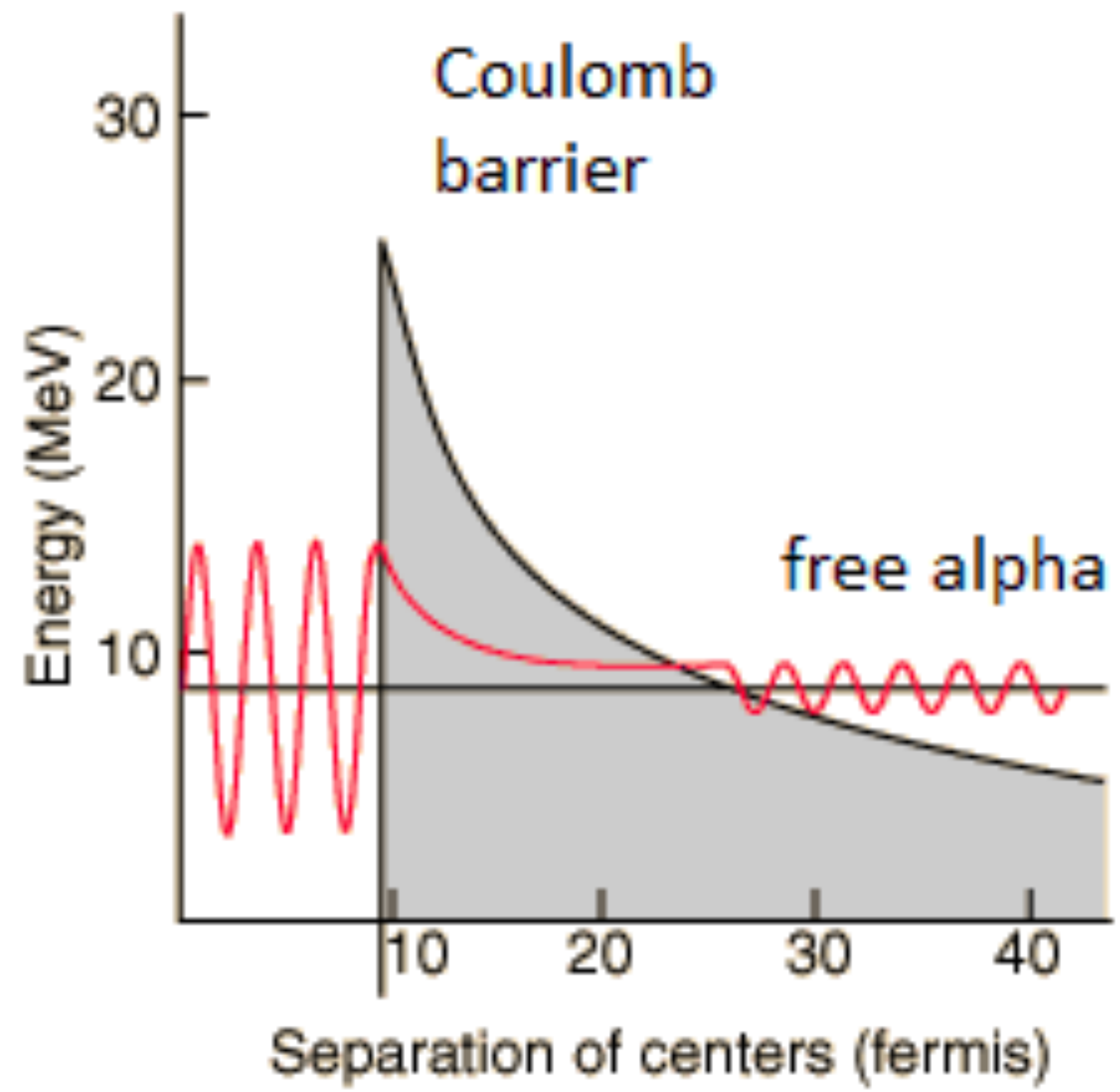


$$ {}^{A}_{Z}X \quad \rightarrow \quad {}^{A-4}_{Z-2}Y + {}^{4}_{2}He $$

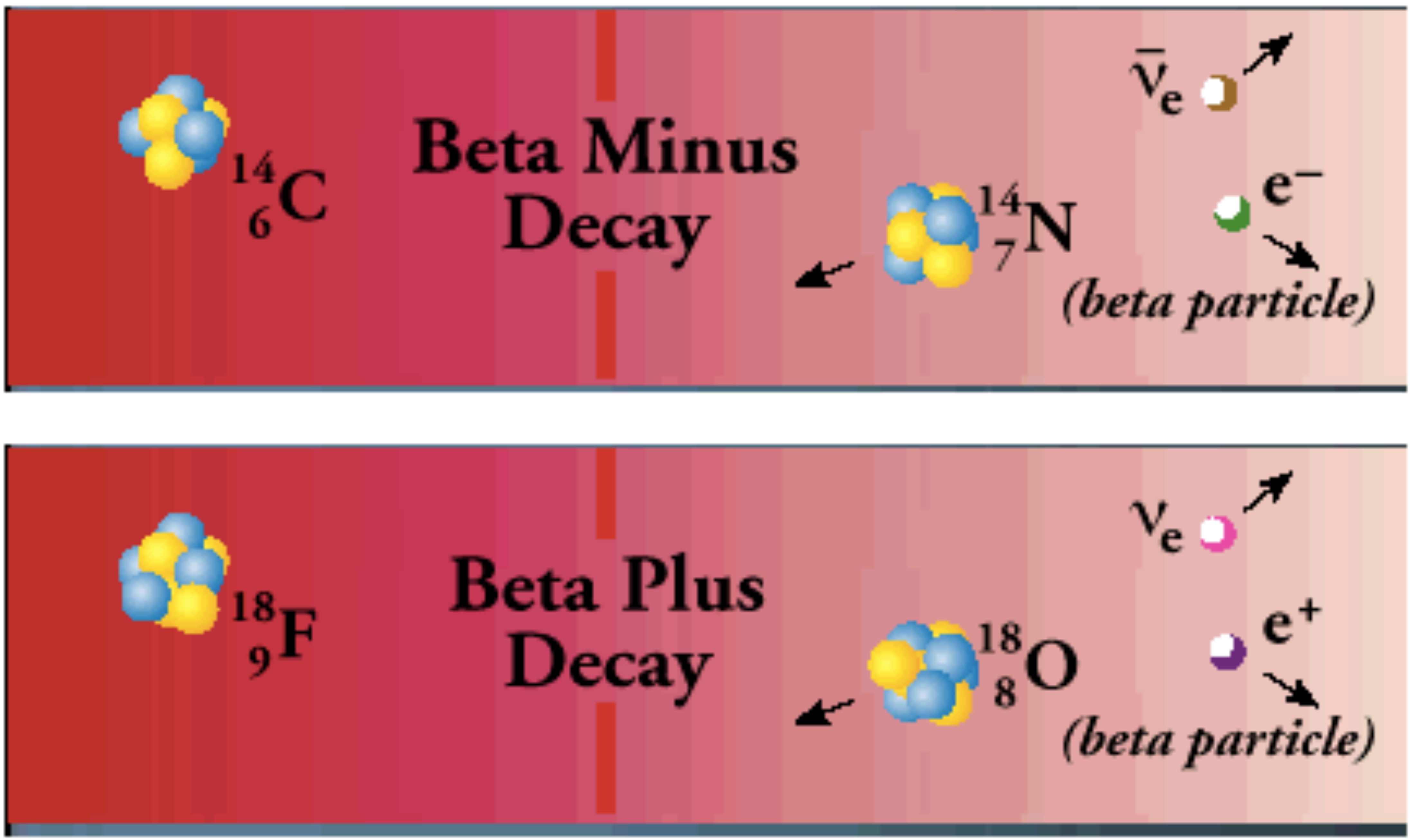
Alpha Decay as Quantum Tunneling

$$^{A}_{Z}X \quad \rightarrow \quad ^{A-4}_{Z-2}Y + ^{4}_{2}He$$

The alpha particle (a helium nucleus, consisting of two protons and two neutrons strongly bound together) is rattling around inside the X nucleus without enough energy to get over the "Coulomb barrier"… unless it ***tunnels through*** the narrow barrier, leaving behind the Y nucleus.



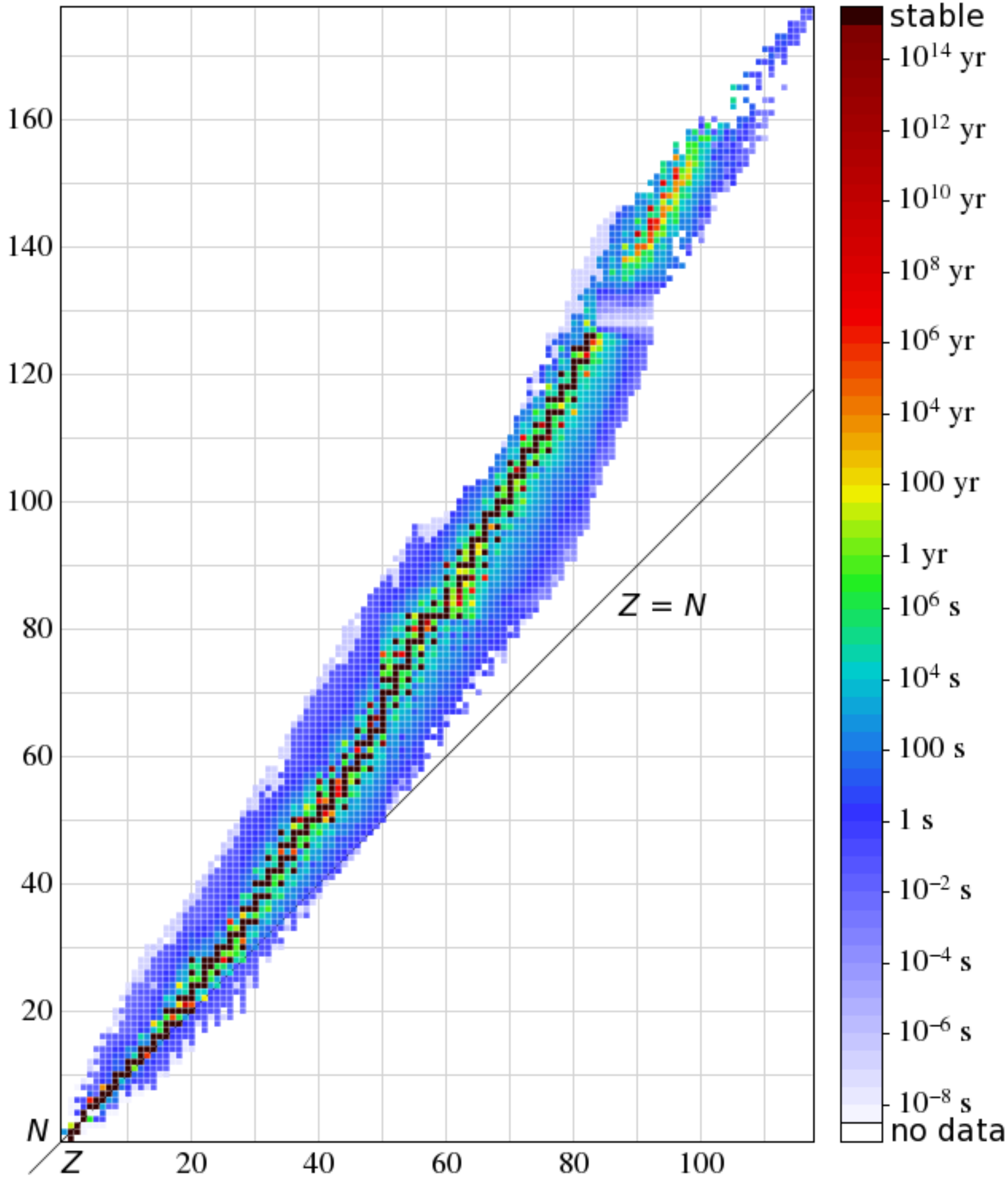
Beta Decay as $n \rightarrow p^{+} + e^{-} + \bar{\nu}_e$



ISOTOPES and their (color-coded) Half-Lives

Z **= # of protons**

N **= # of neutrons**



Decay of Fission Products

Wikipedia: "The radioactivity in the fission product mixture is [initially] mostly *short-lived* isotopes such as ^{131}I and ^{140}Ba; after about four months ^{141}Ce, ^{95}Zr/^{95}Nb and ^{89}Sr take the largest share, while after about two or three years the largest share is taken by ^{144}Ce/^{144}Pr, ^{106}Ru/^{106}Rh and ^{147}Pm."

Medium-lived Daughters

Prop:	$t_{1/2}$	Yield	Q *	βγ *
Unit:	(a)	(%)	(keV)	
^{155}Eu	4.76	0.0803	252	βγ
^{85}Kr	10.76	0.2180	687	βγ
^{113m}Cd	14.1	0.0008	316	β
^{90}Sr	28.9	4.505	2826	β
^{137}Cs	30.23	6.337	1176	βγ
^{121m}Sn	43.9	0.00005	390	βγ
^{151}Sm	88.8	0.5314	77	β

Long-lived Daughters

Nuclide	$t_{1/2}$	Yield	Decay energy[a 1]	Decay mode
	(Ma)	(%)[a 2]	(keV)	
^{99}Tc	0.211	6.1385	294	β
^{126}Sn	0.230	0.1084	4050[a 3]	βγ
^{79}Se	0.327	0.0447	151	β
^{93}Zr	1.53	5.4575	91	βγ
^{135}Cs	2.3	6.9110[a 4]	269	β
^{107}Pd	6.5	1.2499	33	β
^{129}I	15.7	0.8410	194	βγ

Health Concerns

Isotope	Radiation	Half-life	GI absorption	Notes
Strontium-90/yttrium-90	β	28 years	30%	
Caesium-137	β,γ	30 years	100%	
Promethium-147	β	2.6 years	0.01%	
Cerium-144	β,γ	285 days	0.01%	
Ruthenium-106/rhodium-106	β,γ	1.0 years	0.03%	
Zirconium-95	β,γ	65 days	0.01%	
Strontium-89	β	51 days	30%	
Ruthenium-103	β,γ	39.7 days	0.03%	
Niobium-95	β,γ	35 days	0.01%	
Cerium-141	β,γ	33 days	0.01%	
Barium-140/lanthanum-140	β,γ	12.8 days	5%	
Iodine-131	β,γ	8.05 days	100%	
Tritium	β	12.3 years	100%	[a]