Energia di legame nucleare

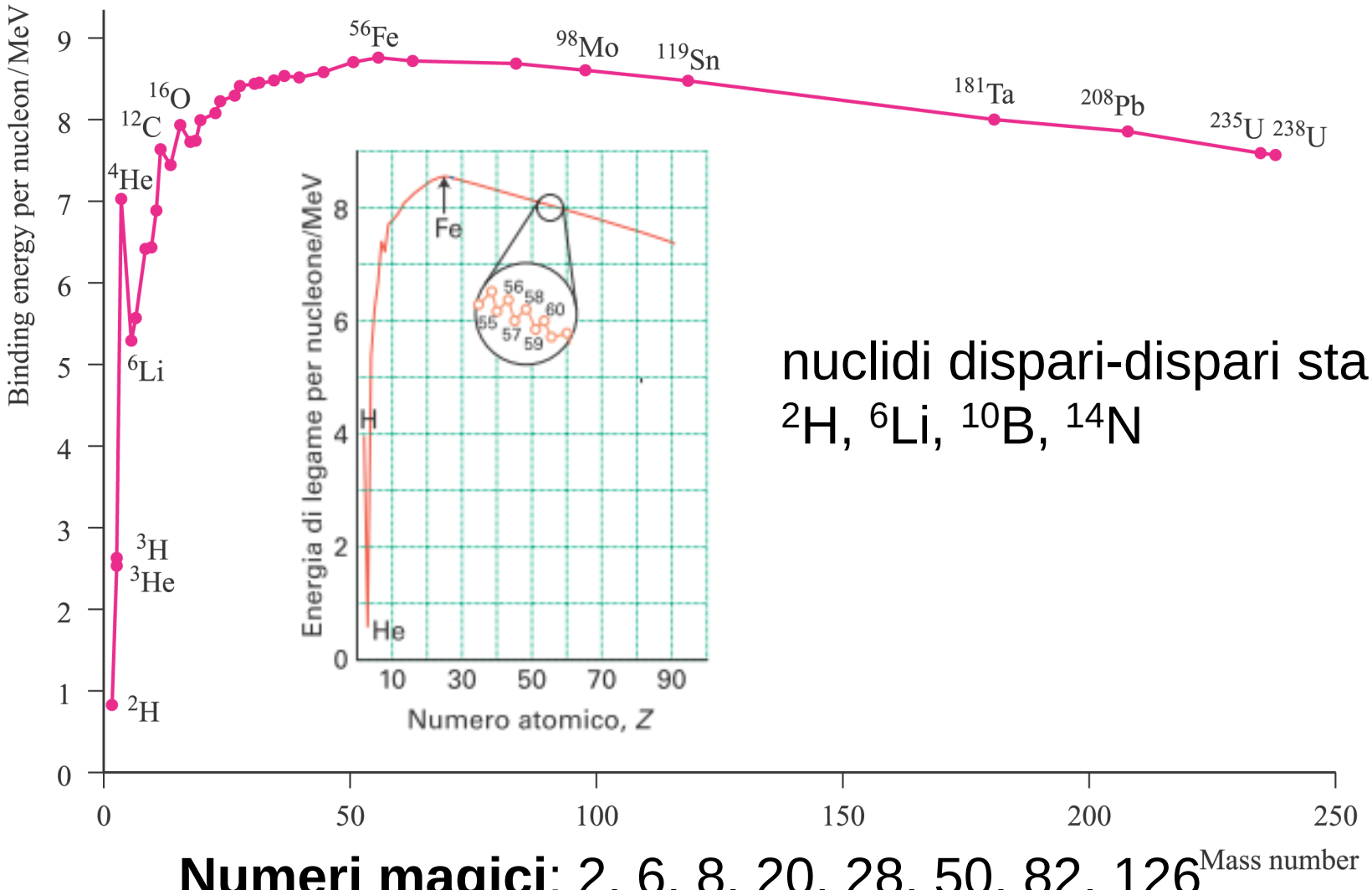
$$\Delta E = \Delta m c^2$$

$C = 2.998 \times 10^8$ m s^{-1}

1 mole ^{7}Li: 3.79×10^9 kJ

1 mole butano: 2857 kJ

Energia per nucleone



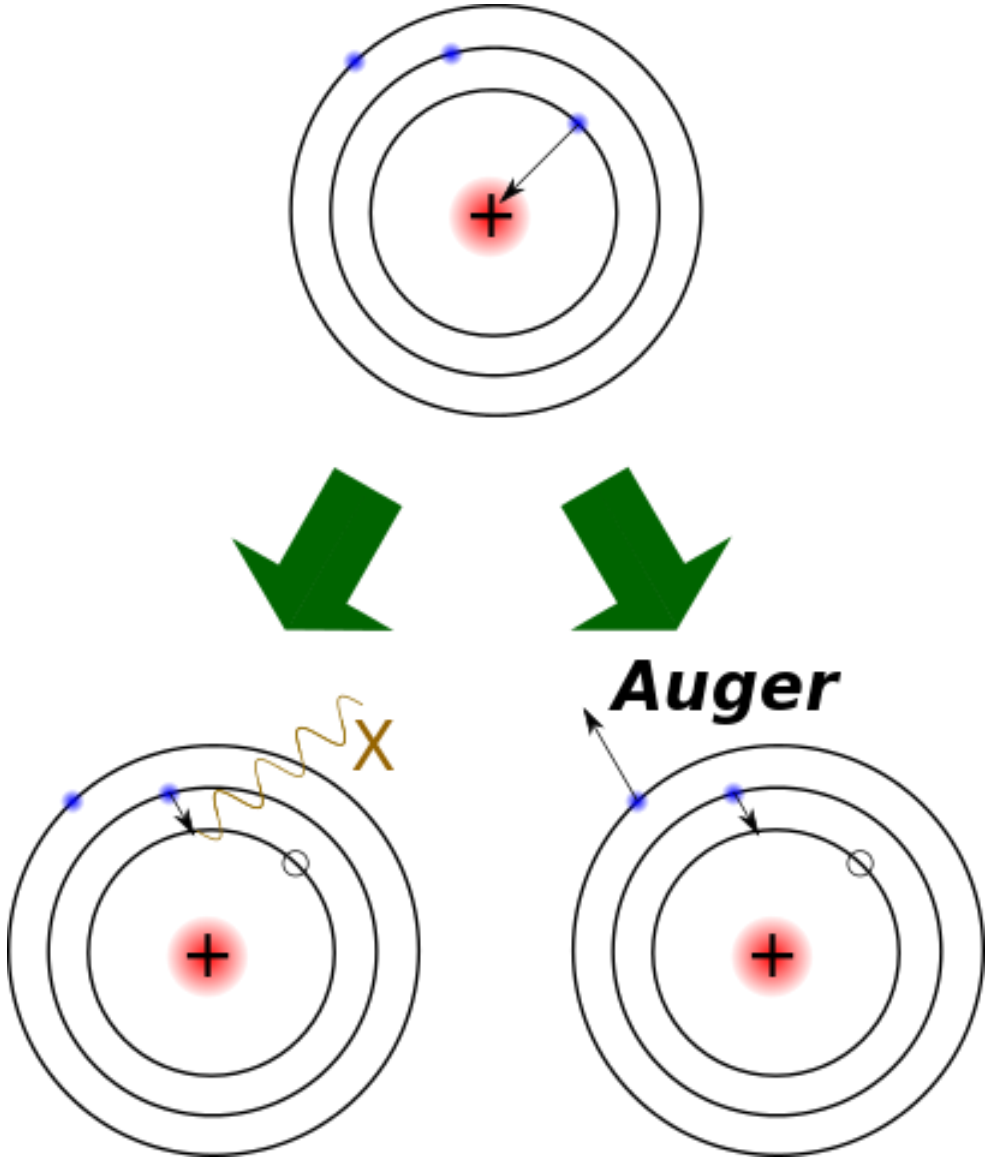
nuclidi dispari-dispari stabili:
^{2}H, ^{6}Li, ^{10}B, ^{14}N

Numeri magici: 2, 6, 8, 20, 28, 50, 82, 126

Processi spontanei nei nuclei radioattivi

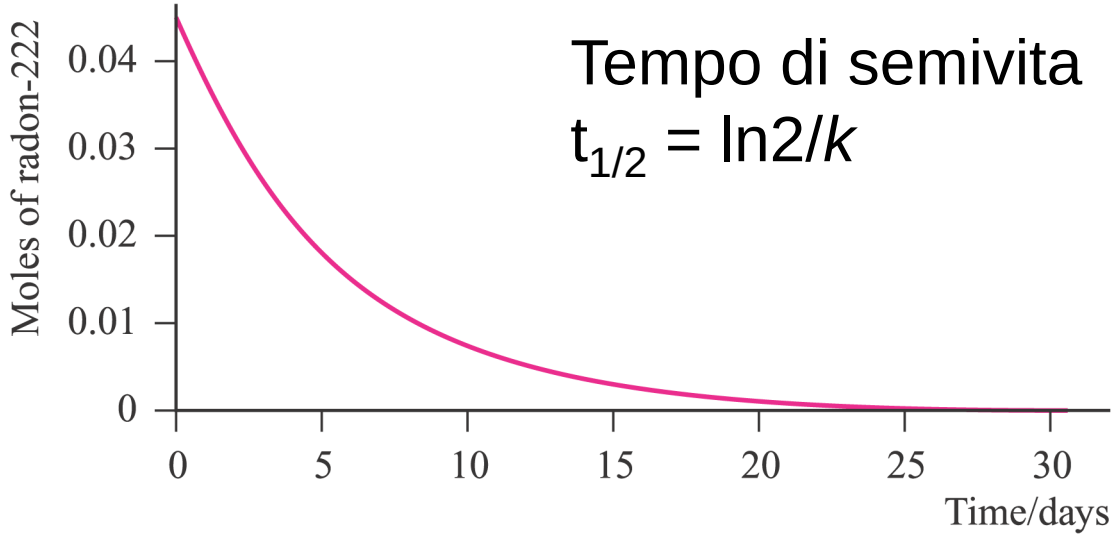
- Emissione di particelle (α, β-, β+)
- Emissione di radiazioni (raggi X, γ)
- Cattura di elettroni
- Fissione

Electron capture (EC)



Decadimento radioattivo del primo ordine di ^{222}Rn

$$N/N_0 = e^{-kt}$$



Tempo di semivita

$t_{1/2} = \ln 2/k$

$$\ln N - \ln N_0 = -kt$$

$$\ln N/2 - \ln N = -kt_{1/2}$$

$$\ln 2 = kt_{1/2}$$

$$\mathbf{t_{1/2} = \ln 2/k}$$

Datazione con il carbonio-14

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^{-} \qquad t_{1/2} = 5730\ a$$

$$^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}H$$

Radiazioni cosmiche

1 becquerel (Bq) = una disintegrazione nucleare per secondo
1 Ci (Curie) = 3.7×10^{10} Bq

$6 – 16 \times 10^{-13}$ J

$0.03 – 5.0 \times 10^{-13}$ J

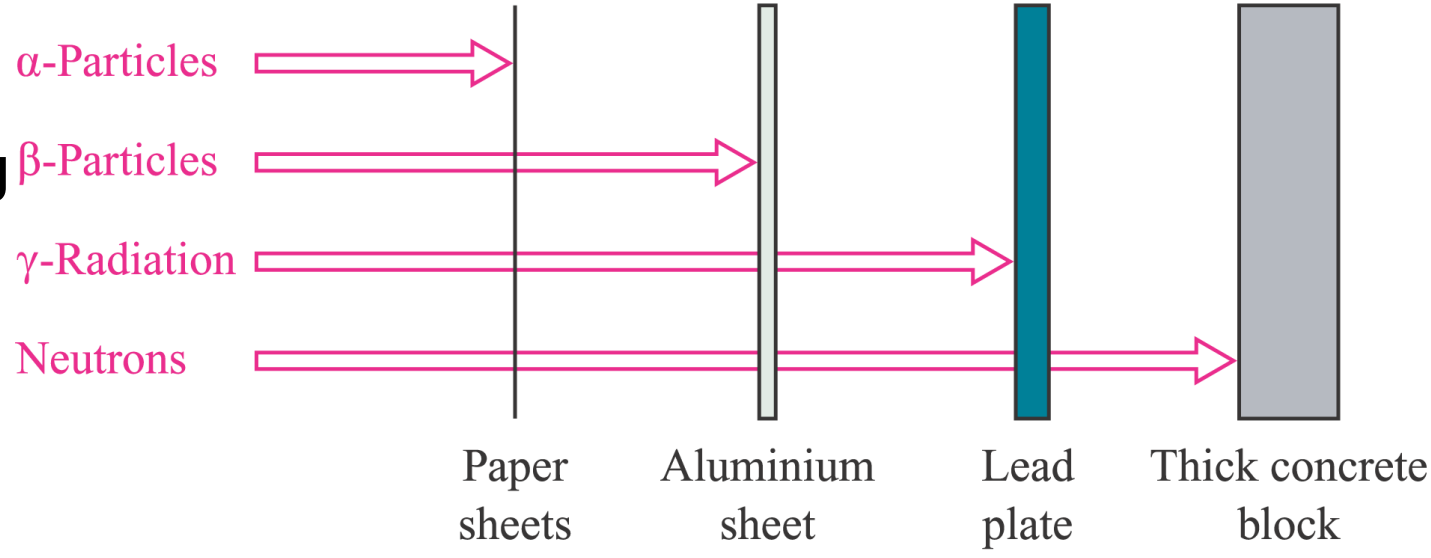
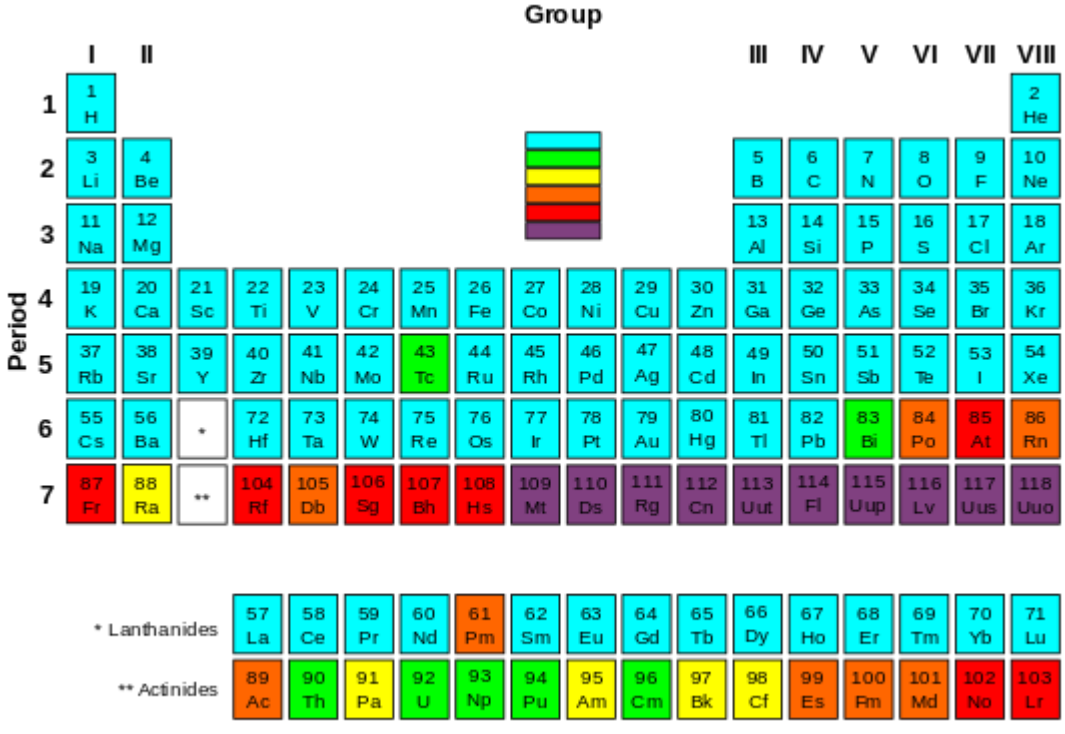
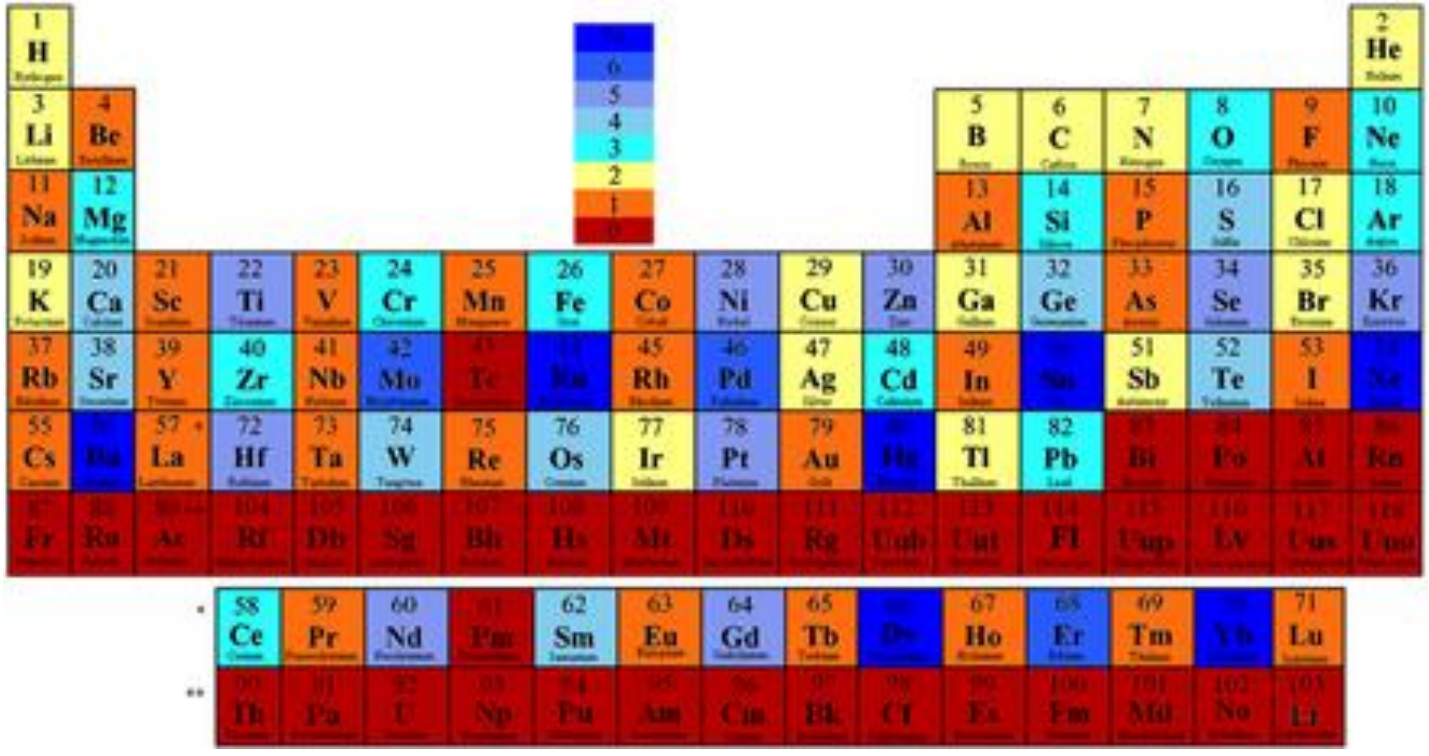


Tavola periodica con gli elementi colorati secondo l'emivita del loro isotopo più stabile



- Elementi stabili
- Elementi radioattivi con isotopi di emivita > 4 milioni di anni. Radioattività molto piccola, se non trascurabile
- Elementi radioattivi che possono presentare bassi rischi per la salute. I loro isotopi più stabili hanno emivite tra 800 e 34 000 anni.

Tavola periodica con il numero degli isotopi stabili



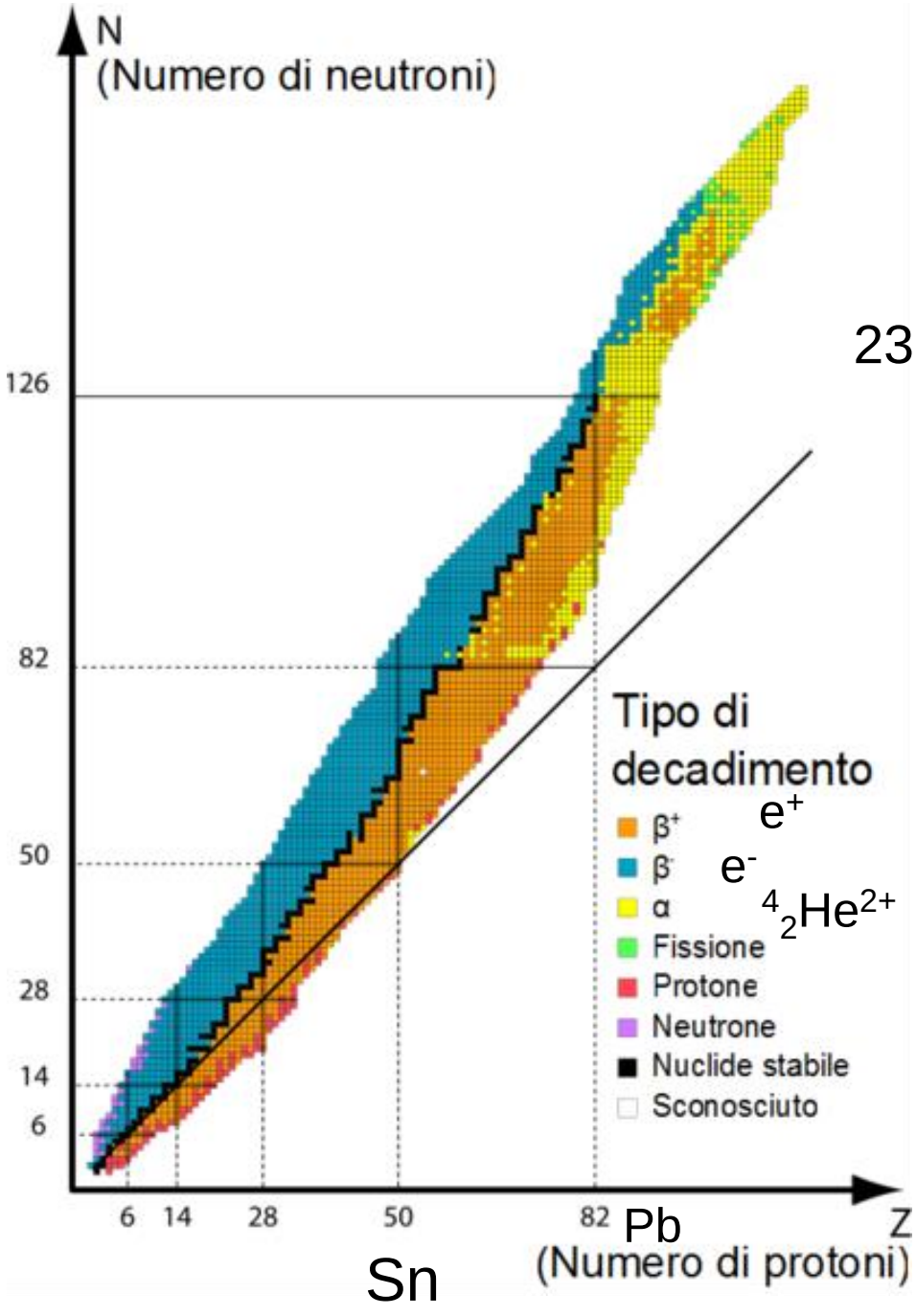
339 nuclidi in natura sulla terra

di cui:

- 255 nuclidi stabili
- 33 nuclidi radioattivi primordiali ($t_{1/2}$ > 80 Ma)
- 51 nuclidi radioattivi ($t_{1/2}$ < 80 Ma) figli o cosmogenici

255+33 = 288 nuclidi primordiali

26 elementi con 1 solo nuclide stabile (25 con *Z* dispari)



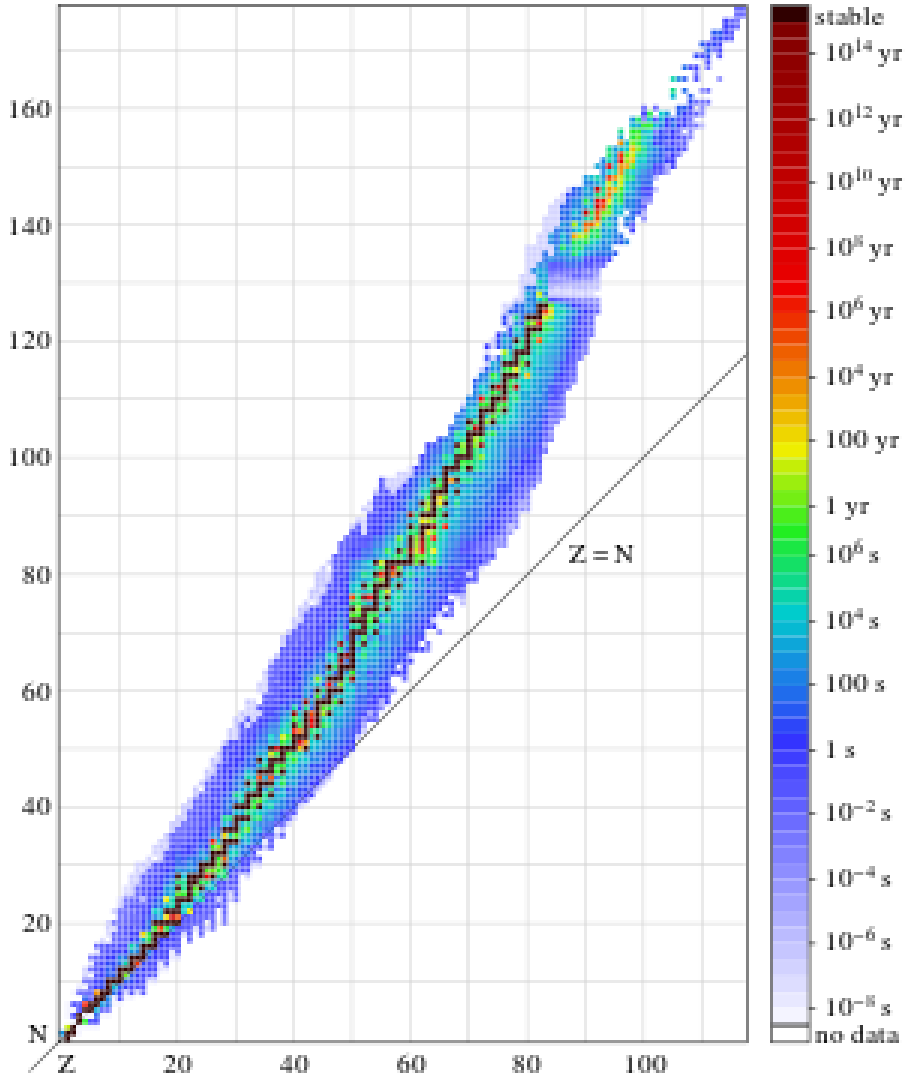
$^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^-$

$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + \gamma$

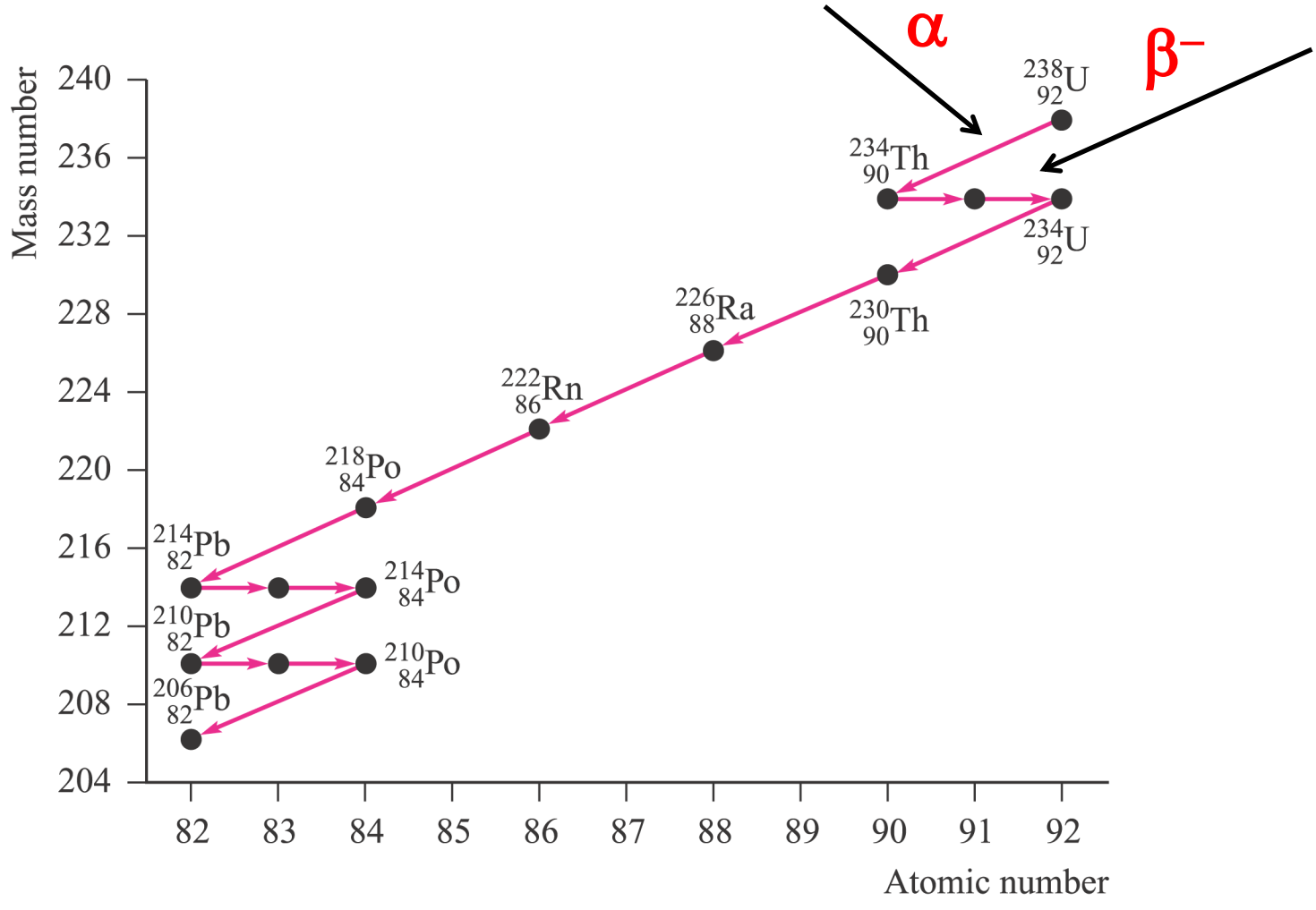
Live Chart of Nuclides

https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

Emivite degli isotopi

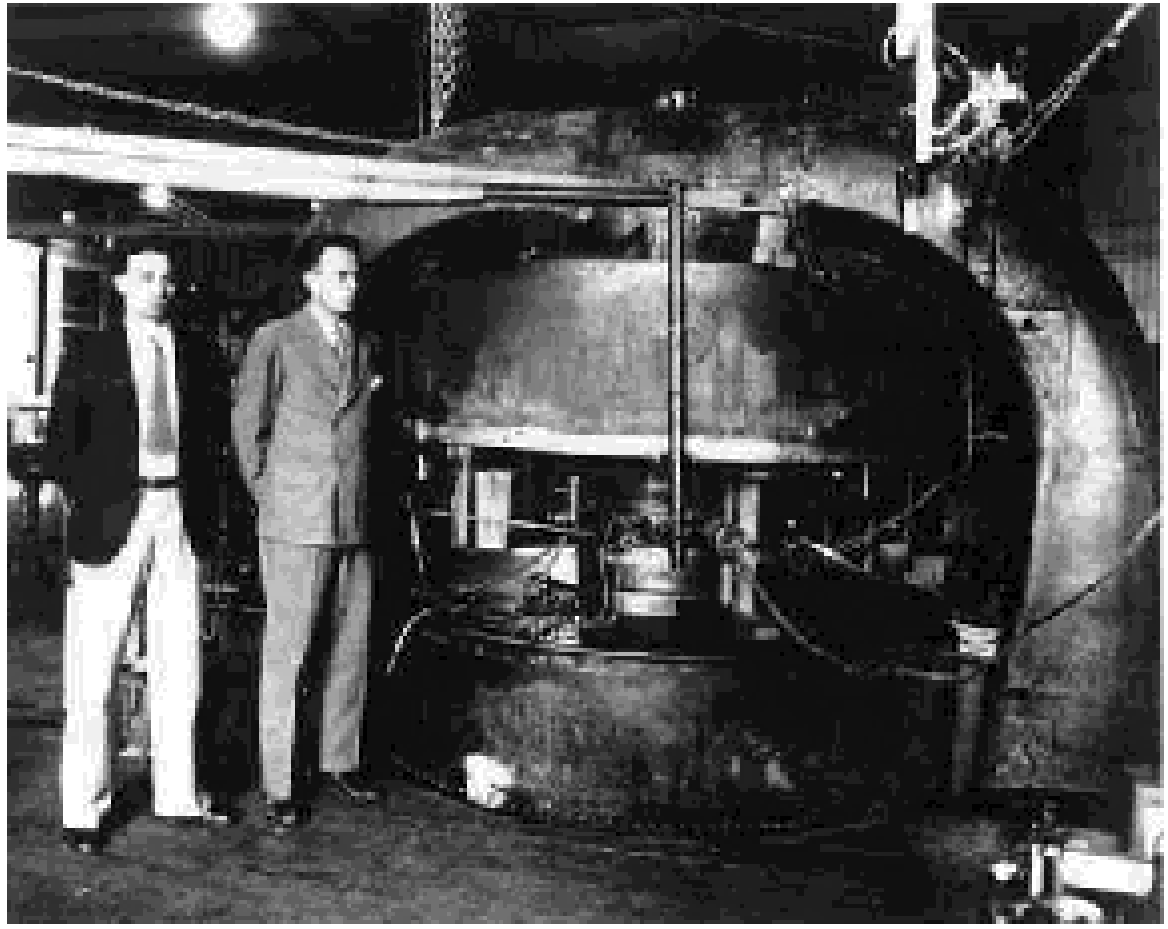


Decadimento in serie



Nuclide	Symbol	Particle emitted	Half-life
Uranium-238	$^{238}_{92}U$	α	4.5×10^9 yr
Thorium-234	$^{234}_{90}Th$	β^-	24.1 d
Protactinium-234	$^{234}_{91}Pa$	β^-	1.18 min
Uranium-234	$^{234}_{92}U$	α	2.48×10^5 yr
Thorium-230	$^{230}_{90}Th$	α	8.0×10^4 yr
Radium-226	$^{226}_{88}Ra$	α	1.62×10^3 yr
Radon-222	$^{222}_{86}Rn$	α	3.82 d
Polonium-218	$^{218}_{84}Po$	α	3.05 min
Lead-214	$^{214}_{82}Pb$	β^-	26.8 min
Bismuth-214	$^{214}_{83}Bi$	β^-	19.7 min
Polonium-214	$^{214}_{84}Po$	α	1.6×10^{-4} s
Lead-210	$^{210}_{82}Pb$	β^-	19.4 yr
Bismuth-210	$^{210}_{83}Bi$	β^-	5.0 d
Polonium-210	$^{210}_{84}Po$	α	138 d
Lead-206	$^{206}_{82}Pb$	None	Non-radioactive

Il primo ciclotrone (Ciclotrone Lawrence, 1931)
Acceleratore di particelle cariche



Isotopi artificiali

Le reazioni nucleari avvengono con la **conservazione del numero atomico e del numero di massa**

$$^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$$

$$^{27}_{13}\mathrm{Al}(\alpha,\mathrm{n})^{30}_{15}\mathrm{P}$$

$$^{30}_{15}\mathrm{P} \rightarrow {}^{30}_{14}\mathrm{Si} + \beta^{+} \qquad t_{1/2} = 3.2\ \mathrm{min}$$

$$^{32}_{16}\mathrm{S} + {}^{1}_{0}\mathrm{n(fast)} \rightarrow {}^{32}_{15}\mathrm{P} + {}^{1}_{1}\mathrm{H}$$

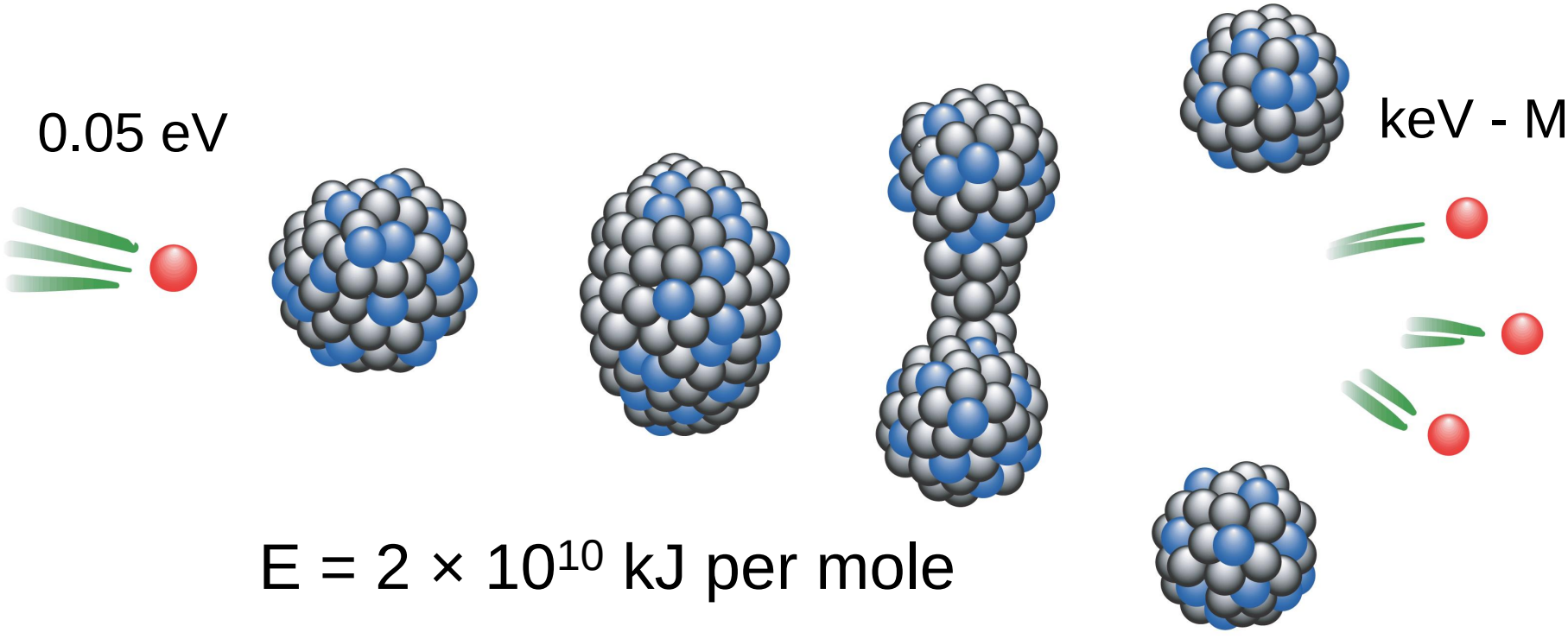
$$^{32}_{15}\mathrm{P} \rightarrow {}^{32}_{16}\mathrm{S} + \beta^{-} \qquad t_{1/2} = 14.3\ \mathrm{d}$$

$$^{31}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n(slow)} \rightarrow {}^{32}_{15}\mathrm{P} + \gamma$$

Reazione (n,γ)

Reazione (n,γ)

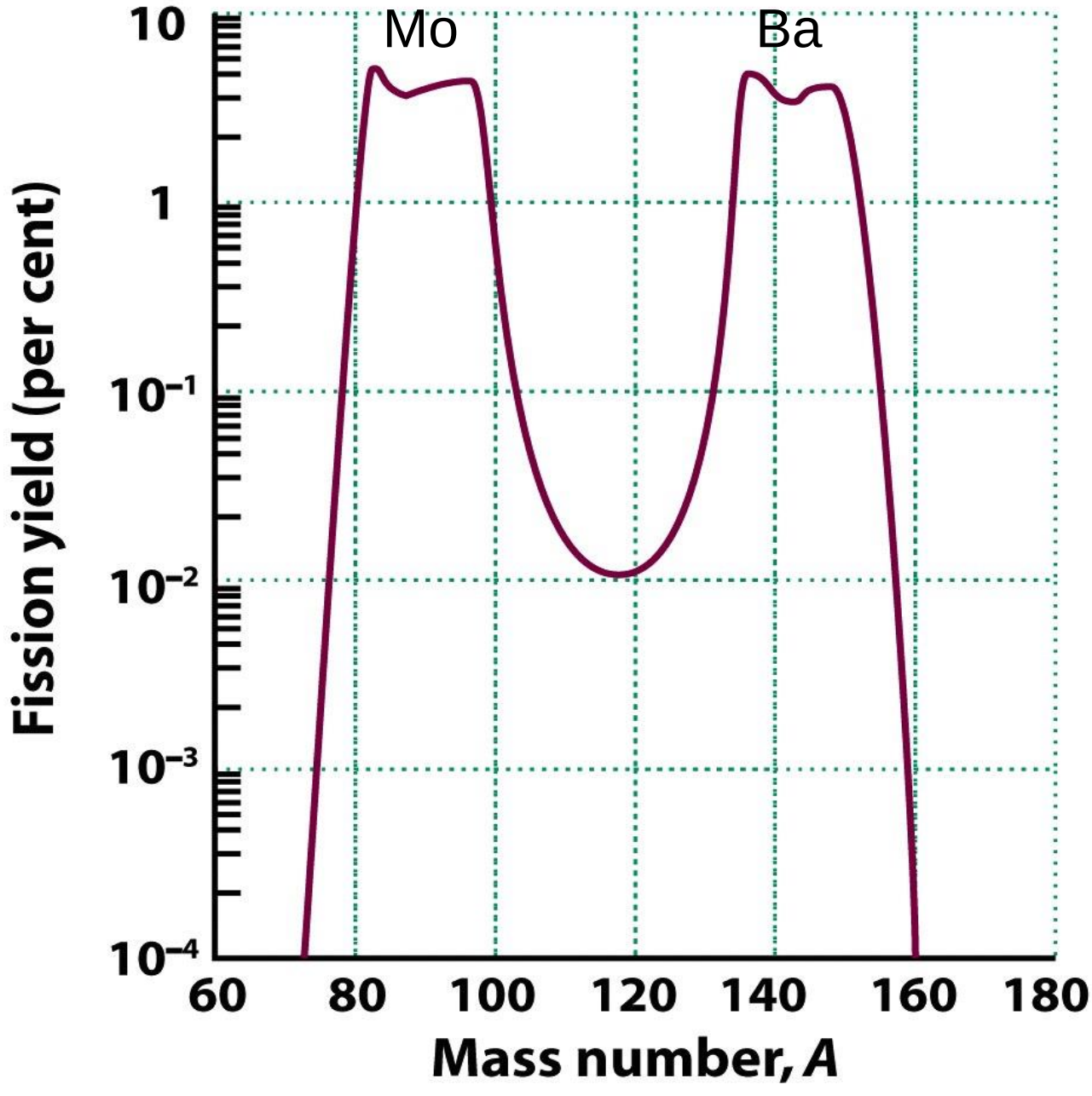
Bombardamento di un nucleo di ^{235}U con neutroni termici



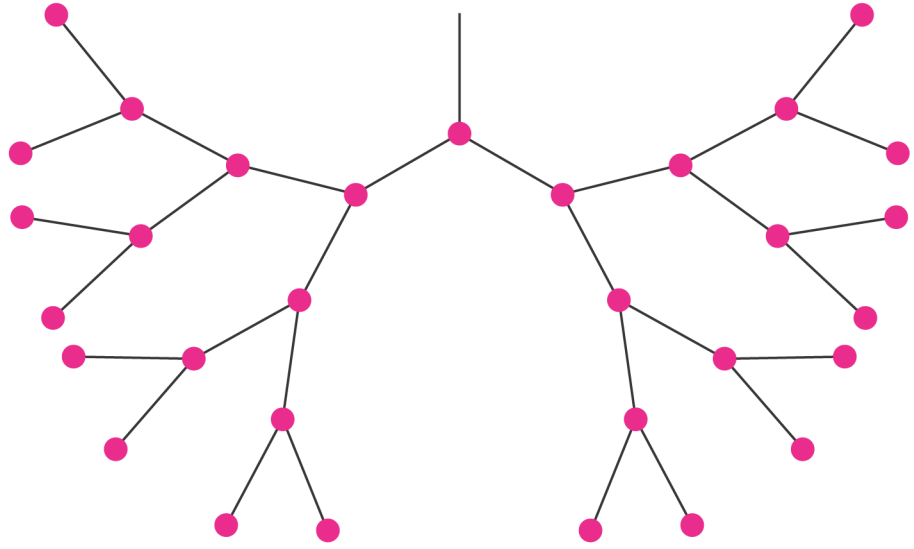
$E = 2 \times 10^{10}$ kJ per mole

$$^{235}_{92}U + {}^{1}_{0}n(\text{slow}) \rightarrow {}^{95}_{39}Y + {}^{138}_{53}I + 3\,{}^{1}_{0}n(\text{fast})$$

^{235}U = ca. 0.72% dell'uranio naturale


Mo
Ba
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Fission yield (per cent)
60
80
100
120
140
160
180
Mass number, A

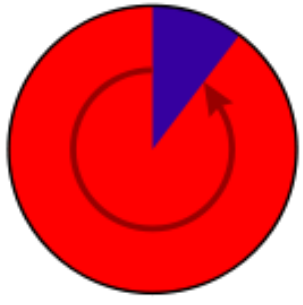
Reazione a catena



- Grafite o D_2O per rallentare i neutroni
- Acciaio al boro, carburo di boro o carburo di cadmio per catturare i neutroni (B e Cd hanno alte sezioni d'urto per la cattura)

Natural uranium
> 99.2% U-238
0.72% U-235

Low-enriched uranium
(reactor grade)
3-4% U-235



Highly enriched uranium
(weapons grade)
90% U-235

Trasformazione dell'uranile in UF_6

$[UO_2][NO_3]_2 \rightarrow UO_3 + NO + NO_2 + O_2$ (a 570 K)

$UO_3 + H_2 \rightarrow UO_2 + H_2O$ (a 970 K)

$UO_2 + 4HF \rightarrow UF_4 + 2H_2O$

$UF_4 + F_2 \rightarrow UF_6$ (a 720 K)

Centrifughe per la separazione della miscela di $^{235}UF_6$ e $^{238}UF_6$ sfruttando la legge di Graham