particelle conosciute: γ, e^-, p, n

Interazioni interessate

EM.

debole

forte

p, n: adroni: interagiscono forza forte.

barioni: $(q_1 q_2 q_3)$

mesoni $q_1 \bar{q}_2$

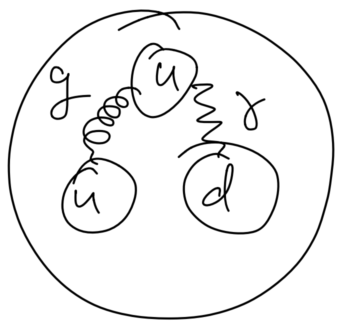
carica elettrica

$$\begin{pmatrix} up \\ down \end{pmatrix} \begin{pmatrix} charm \\ strange \end{pmatrix} \begin{pmatrix} top \\ bottom \\ beauty \end{pmatrix} \quad \begin{matrix} +2/3 \\ -1/3 \end{matrix}$$

$$\begin{matrix} -2/3 \\ +1/3 \end{matrix} \quad \begin{pmatrix} \bar{u} \\ \bar{d} \end{pmatrix} \begin{pmatrix} \bar{c} \\ \bar{s} \end{pmatrix} \begin{pmatrix} \bar{t} \\ \bar{b} \end{pmatrix}$$

fermioni

$$\begin{array}{c} \quad\quad q \\ \begin{pmatrix} u & +\frac{2}{3} \\ u & +\frac{2}{3} \\ d & -\frac{1}{3} \end{pmatrix} \end{array} \equiv p$$



$$\begin{pmatrix} u \\ d \\ d \end{pmatrix} \equiv n$$

$$uuu = 3 \times \frac{2}{3} = +2$$

Barioni $q_1 q_2 q_3$

$\bar{p} = (\bar{u}\bar{u}\bar{d})$

mesoni: $q_1 \bar{q}_2$ $\quad \begin{pmatrix} u \\ \bar{d} \end{pmatrix}$ $\quad q = +\frac{2}{3} + \left(+\frac{1}{3}\right) = +1$

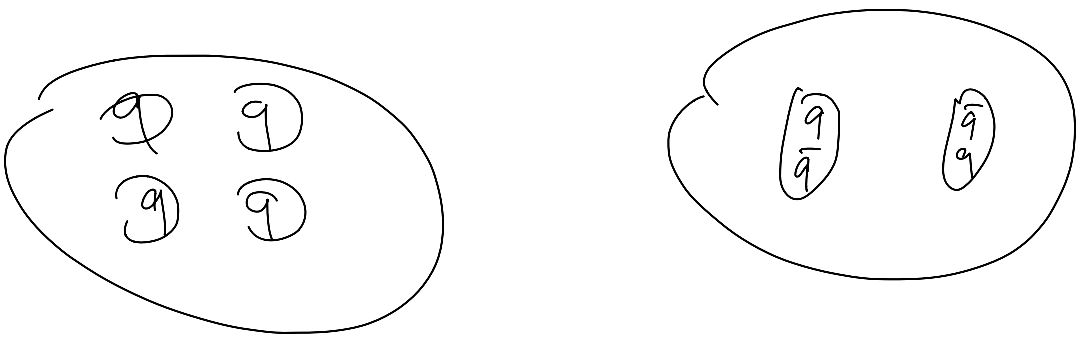
π^+ $\quad m \sim 140$ MeV

$\begin{pmatrix} \bar{u} \\ d \end{pmatrix}$ π^-

$\begin{array}{c c} -\frac{2}{3} & \multirow{2}{*}{$\begin{pmatrix} \bar{u} \\ s \end{pmatrix}$} \\ -\frac{1}{3} & \end{array}$ K^- $\quad \begin{pmatrix} \bar{d} \\ s \end{pmatrix} \equiv \bar{K}^0$ $\quad \begin{pmatrix} d \\ \bar{s} \end{pmatrix} \equiv K^0$

~ 500 MeV

adroni: mesoni / barioni


tetraquark

in natura non esistono quark liberi

adroni: forte, EM (970), debole

leptoni: interagiscono debole e EM.

$q_{elet} = -1$ $\quad \begin{pmatrix} e^- \\ 0.511\ \text{MeV} \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu^- \\ 106\ \text{MeV} \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau^- \\ 1.8\ \text{GeV} \\ \nu_\tau \end{pmatrix}$

$= 0$

$q=+1$ $\quad \begin{pmatrix} e^+ \\ \bar{\nu}_e \end{pmatrix} \begin{pmatrix} \mu^+ \\ \bar{\nu}_\mu \end{pmatrix} \begin{pmatrix} \tau^+ \\ \bar{\nu}_\tau \end{pmatrix}$ fermioni

$q=0$

$$m_{e^-} \equiv m_{e^+}$$

$$\mu^+ \; \mu^-$$
$$m \equiv m$$
$$\tau \equiv \tau$$

γ: spin $=1$ bosone.

portatore di forze

bosoni di gauge vettori $(s=1)$ intermedi

$m_\gamma = 0$.

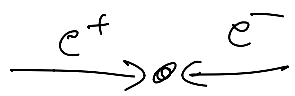
media le forze EM

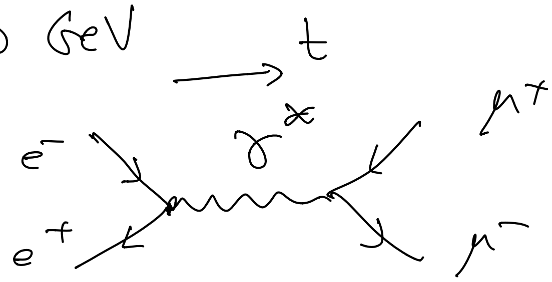
gluoni g: portatori di forze forte.

$m_g = 0$.

$W^\pm, Z^0$: mediatori di forze debole

$$m_W \simeq 80 \text{ GeV}$$
$$m_Z \simeq 90 \text{ GeV}$$





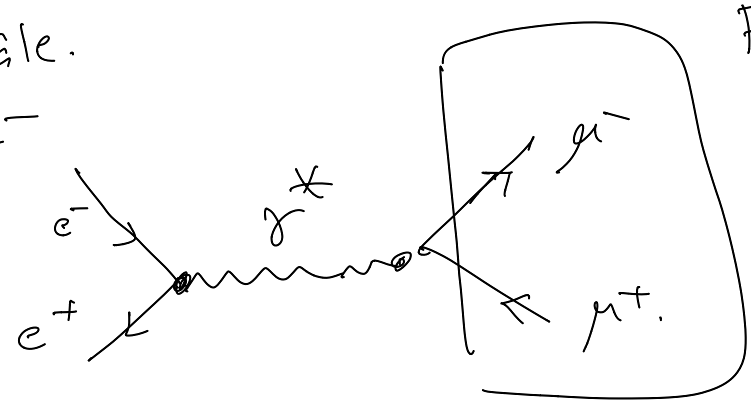
$$e^+ + e^- \longrightarrow \mu^+ + \mu^-$$

$m_e = 0.511$ MeV $\qquad m_\mu = 106$ MeV.

$E_f = 212$ MeV. $\Rightarrow$ $P_{cf} \neq 106$ MeV.

iniziale. Finale.

$e^+ + e^-$



$$e^+ + e^- \longrightarrow \mu^+ + \mu^-$$

In tutte le reazioni note. si conservano.

- \# barionico.
- \# leptonico.

$$\begin{array}{c} L_e \\ +1 \\ +1 \end{array} \begin{pmatrix} e^- \\ \nu_e \end{pmatrix} \qquad \begin{pmatrix} e^+ \\ \bar{\nu}_e \end{pmatrix} \begin{array}{c} L_e \\ -1 \\ -1 \end{array}$$

$p \quad B = +1. \qquad \bar{p} : B = -1$

$$L_e\Big|_{in} - L_e\Big|_{f} = \Delta L_e = 0.$$

$$\Delta B = 0. \quad \longleftrightarrow \quad B_{fin} = B_{in}.$$

	e^+	$+ e^-$	$\longrightarrow$	μ^+	$+ \mu^-$
L_e	-1	$+1$		0	0
L_μ	0	0		-1	$+1$
L_τ	0	0		0	0
B	0	0		0	0

$$p + p \longrightarrow p + p + p + \bar{p}$$
$$B \quad +1 \quad +1 \qquad +1 \quad +1 \quad +1 \quad -1$$
$$B_{in} = 2 \qquad\qquad B_{fin} = 2$$

$$p + p \longrightarrow p + \bar{p}$$
$$B \quad +1 \quad +1 \qquad +1 \quad -1$$
$$B_{in} = +2 \qquad B_{fin} = \emptyset$$

$$p + p \longrightarrow p + p$$

mecc. lag.: inv. sotto una trasf $\Longrightarrow$ conservazione di una quantità

$$L = L(r, \theta)$$

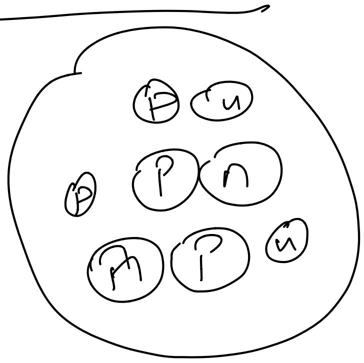
$$\frac{\partial L}{\partial \varphi} = 0 \Rightarrow \frac{d}{dt}\frac{\partial L}{\partial \dot{\varphi}} = 0 \Longrightarrow \frac{\partial L}{\partial \dot{\varphi}} \equiv \text{cost.}$$

Teorema Nöther

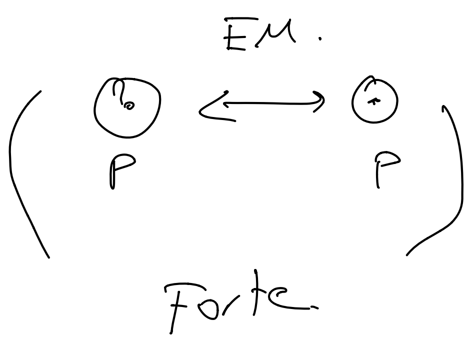
quantità conservate $\longleftrightarrow$ simmetria (invar. sotto una trasf.)

B, L_e, L_μ, L_τ si conservano $\Longrightarrow$ esiste una simmetria.

Fisica nucleare



nucleo.



A, Z

Z: # protoni $\qquad$ Carica elettrica $= Ze$

A : numero di massa.

$$A = Z + N$$

Z ↓ protoni, N ↓ neutroni

nuclidi : (A, Z) nucleone : { protone, neutrone.

A nucleoni

Z protoni

$A - Z$: neutroni

isotopi : nuclidi con lo stesso Z, diverso A.

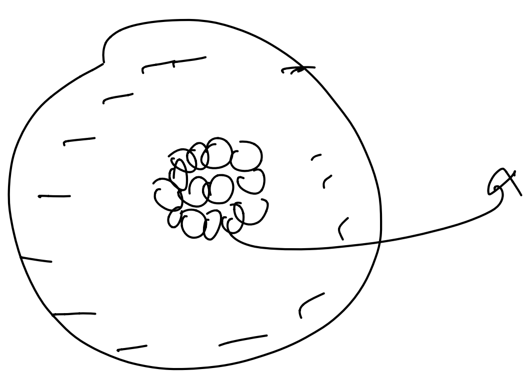
$^{12}_{6}C$ 98.9% $Z = 6$, $N = 6$.

$^{13}_{6}C$ 1.1% $Z = 6$, $N = 7$

isobari : nuclidi con lo stesso A, diverso Z

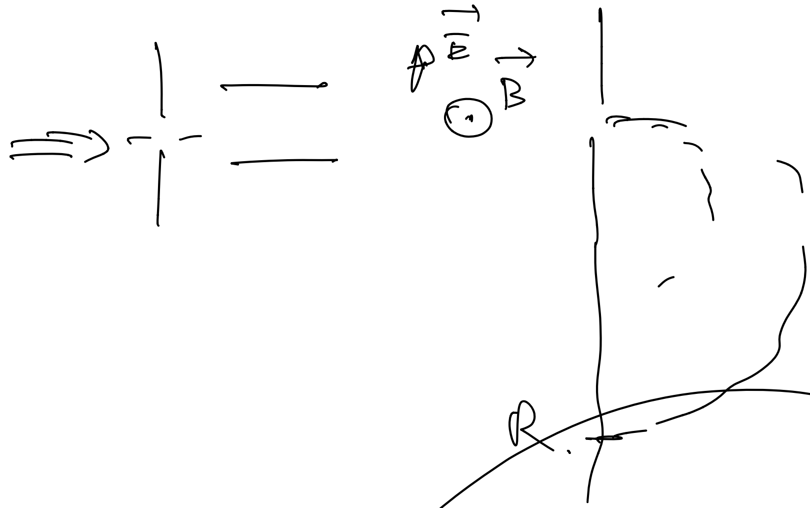
$A \longrightarrow$ massa del nuclide

$Z \longrightarrow$ carica

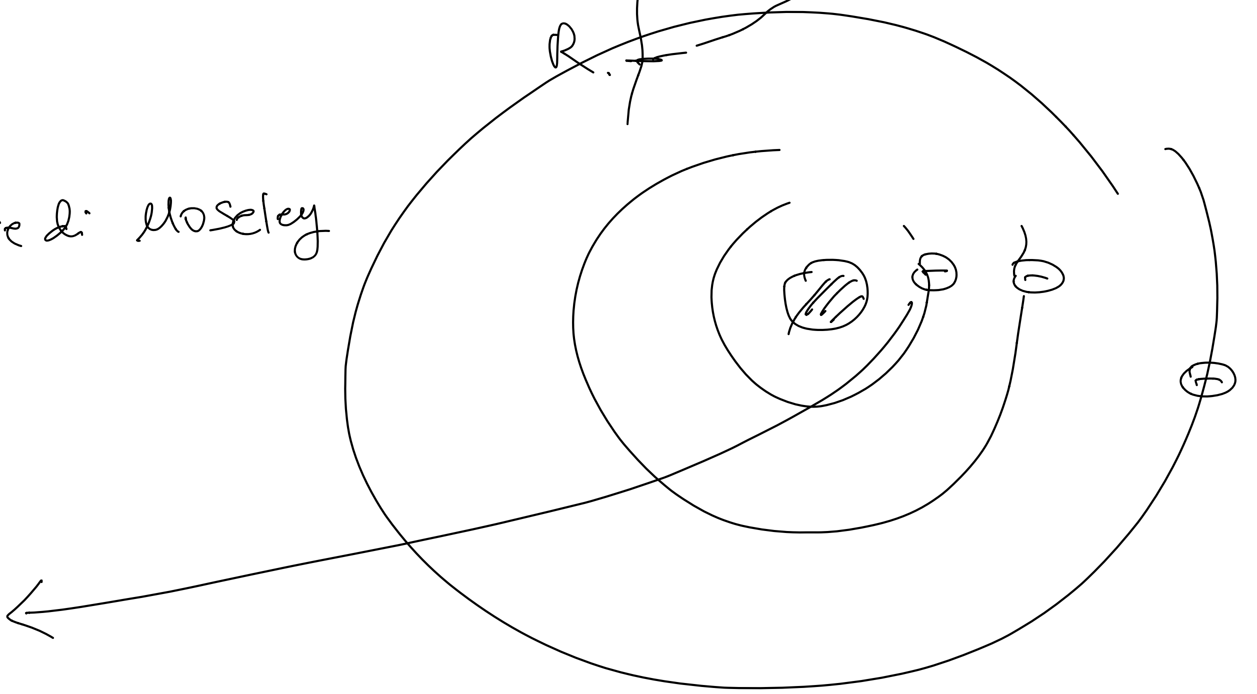


massa ?

masse: spettrometro di massa.



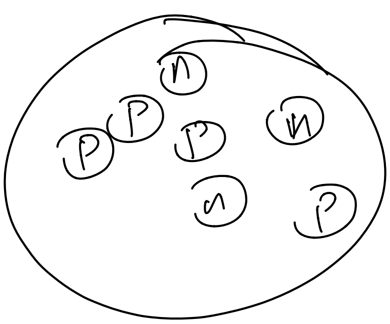
Legge di Moseley



$$E_e \simeq \frac{3}{4} Ry\,(Z-1)^2 \qquad Ry = 13.6\ eV.$$

$$\simeq 10\,eV\,(Z-1)^2$$

spettro raggi X $\Longrightarrow$ stime di Z.



(A, Z)

$M(A,Z)$: massa di nuclide (A,Z).

$$M(A,Z) < Z \cdot m_p + (A-Z)\, m_n$$

nei sistemi legati: energia di legame.

$$B(Z,A) = Z\, M(^1_1H) + (A-Z)\, m_n - \underbrace{M(Z,A)}_{\text{massa nuclide.}}$$

$\underbrace{B(Z,A)}$

energia di legame

$$M(^1_1H) = m_p + m_e + B_e$$

MeV 939. 0.511 13.6 eV

$\simeq m_p$.

Per definizione $B(Z,A) > 0$

$$M(^1_1H) = 938.9 \text{ MeV} = 1.008 \text{ uA}$$

$$1 \text{ uA} = \frac{1}{12} \underbrace{M(^{12}_{6}C)}_{\text{massa atomica.}} = 931.494 \text{ MeV.}$$

$m_p \simeq 939$ MeV.

$m_n \simeq 938$ MeV.

$B(Z,A) = ?$ energia di legame nucleare.

^1_1H $(A=1, Z=1)$

$B(1,1) = 0$

deuterio. ^2_1H p n

nucleo di deutone

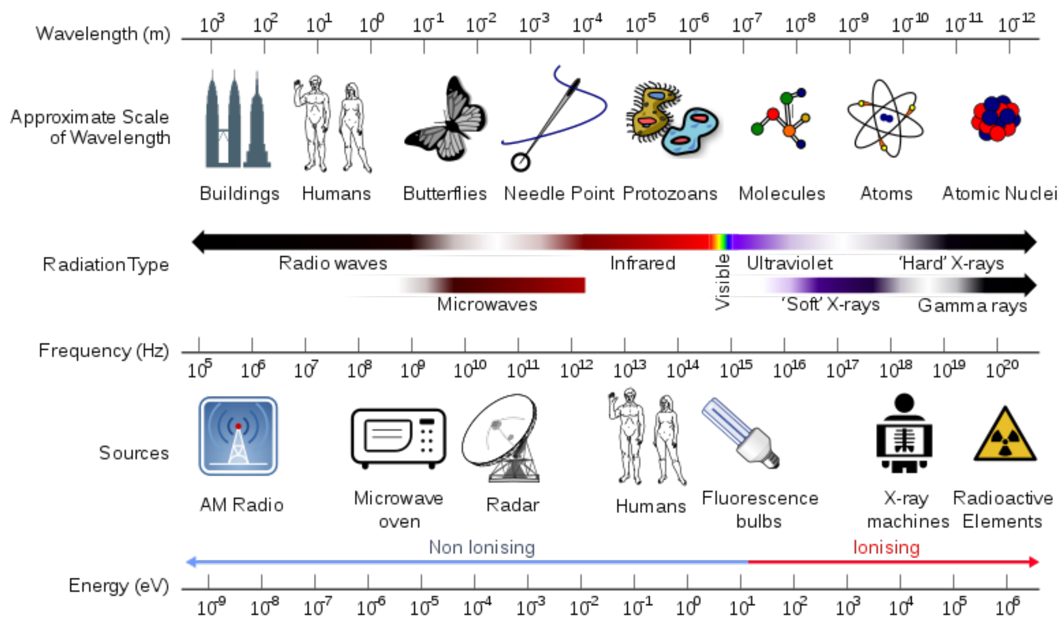
$$B(Z=1, A=2) = M(^2_1H) - m_n - m(^1_1H)$$

$$= 2.225 \text{ MeV.}$$

$=$

Ry ≈ 13.6 eV. en. di legame atomico.

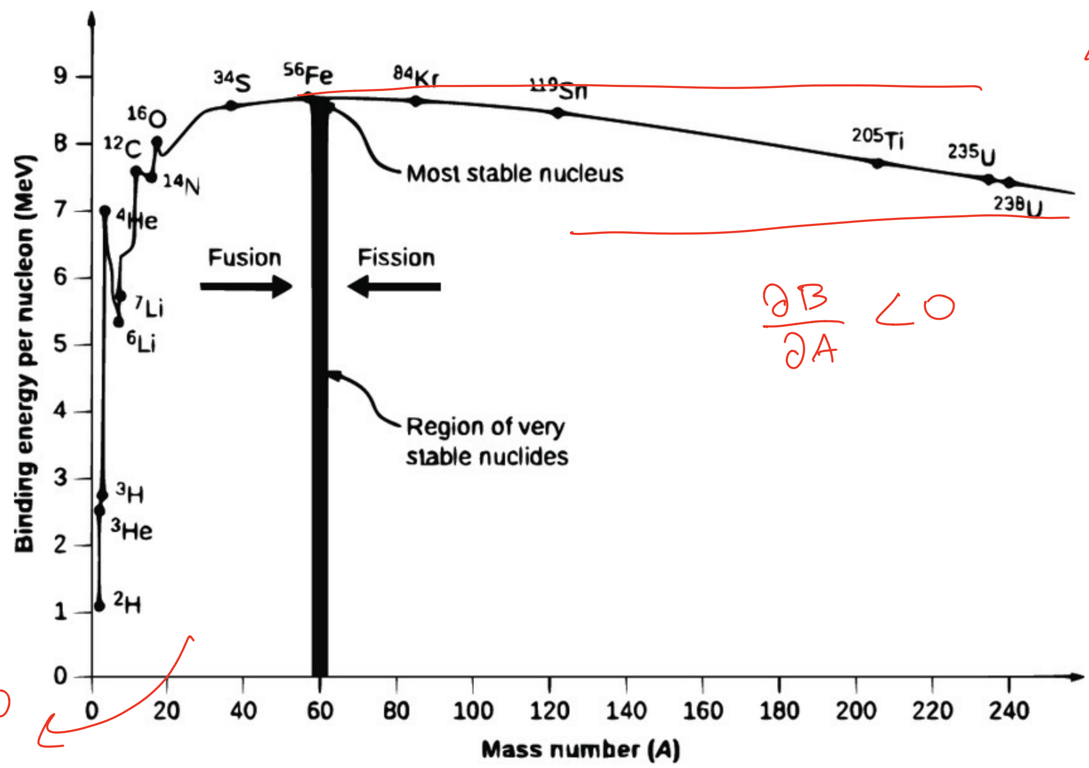
10^5 più grande, energia di legame.



$B(Z,A)$ dipendenza da Z, A,

si considera / misura $\frac{B(Z,A)}{A}$: energia di legame medio per nucleone.

$\frac{B(Z,A)}{A}$



MeV

8.5

7.5

$\frac{\partial B}{\partial A} < 0$

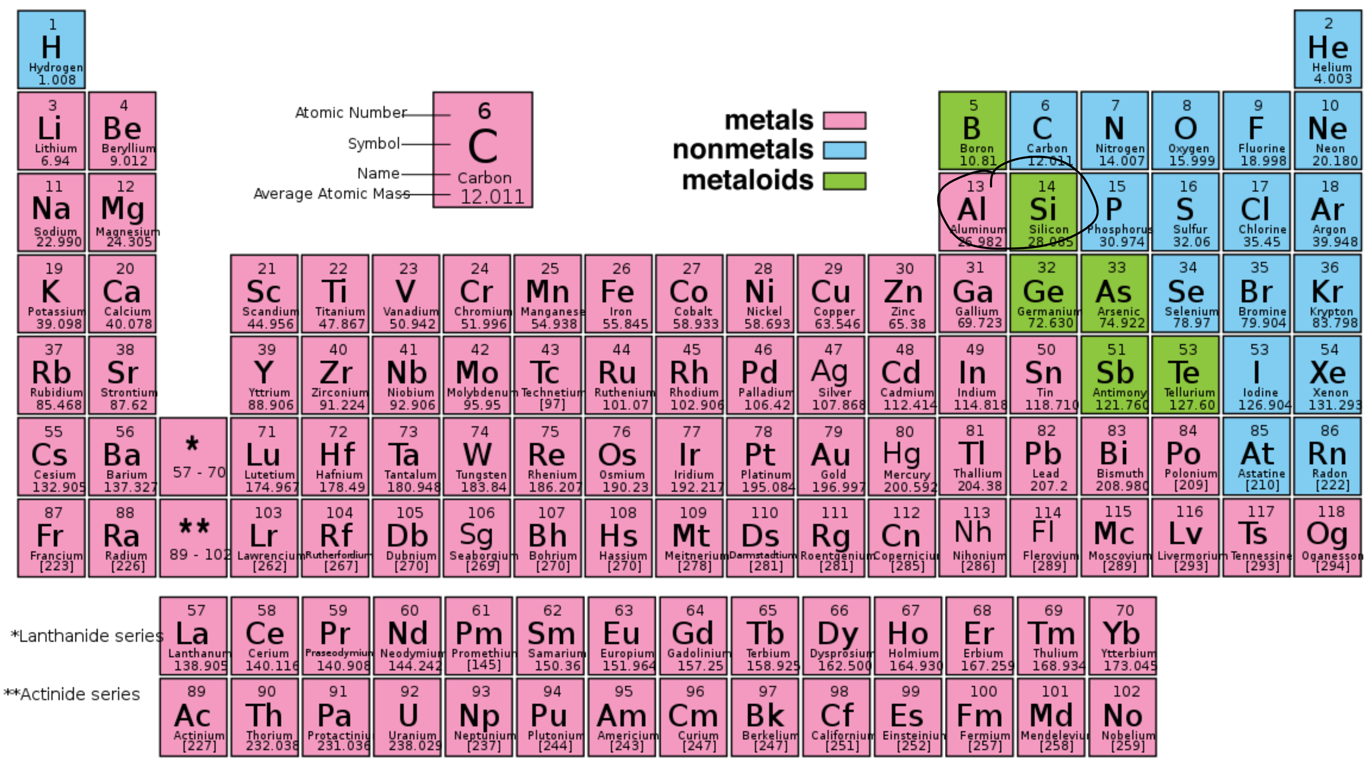
$\frac{\partial B}{\partial A} > 0$

$\alpha \equiv {}^4_2He \qquad \frac{B(4,2)}{4} \simeq 7$ MeV

Fissione: $A > 60$ possibile.

avviene soprattutto per $A > 200$

$A < 60$: Fusione



nuclidi: non sono tutti stabili.

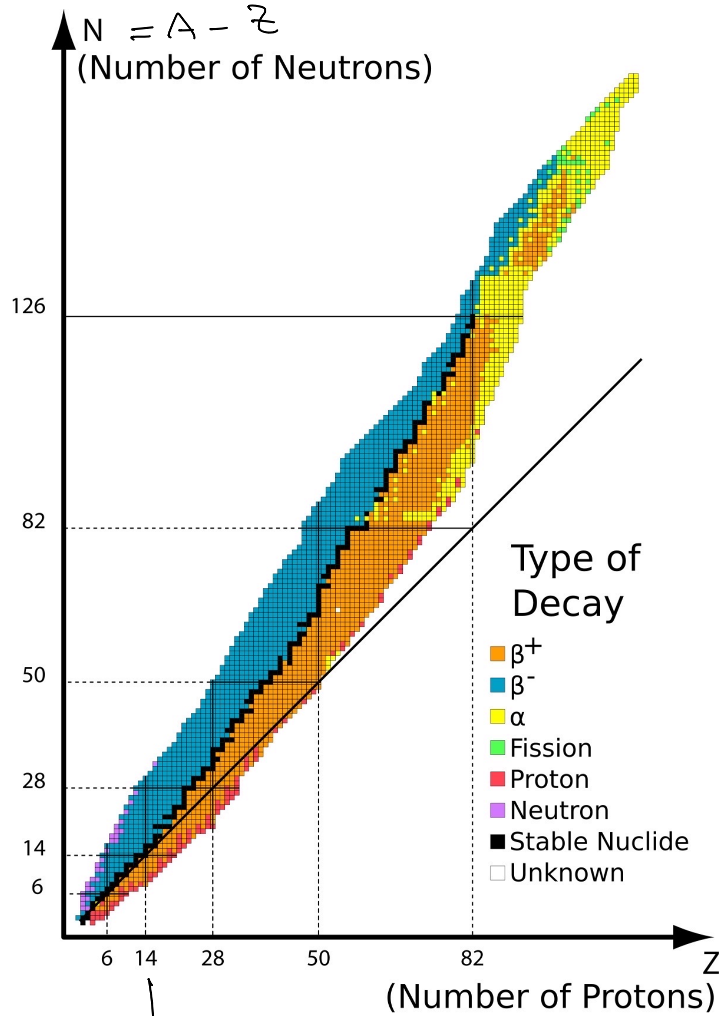
alcuni decadono spontaneamente.

$$A \longrightarrow B + C.$$

$${}^A_Z N \longrightarrow {}^4_2He + {}^{A-4}_{Z-2}X$$

$B_{in} = A. \qquad B_{fin} = 4 + A - 4 = A.$

Carta di Segrè



$Z = 14$ Si

$Z < 14$

$N = A - Z > Z.$

$A > 2Z.$

eccesso di neutroni nei nuclei stabili.

$Z \simeq A - Z.$

$\Rightarrow A \simeq 2Z$