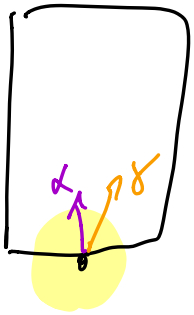
(E3) "sfera"



2 MeV/(g/cm²)

$\rho_{Cu} > 1\ g/cm^3$

→ 2 MeV/cm

$\sigma(\gamma + \text{materia})$

$$\lambda = \frac{1}{\sigma \cdot n_B}$$

$R = R_0 A^{1/3}$ ○ "sfera"

$$M(A,Z) \overset{(c=1)}{=} Z \cdot m_p + (A-Z)\, m_n - E_L(A,Z)$$

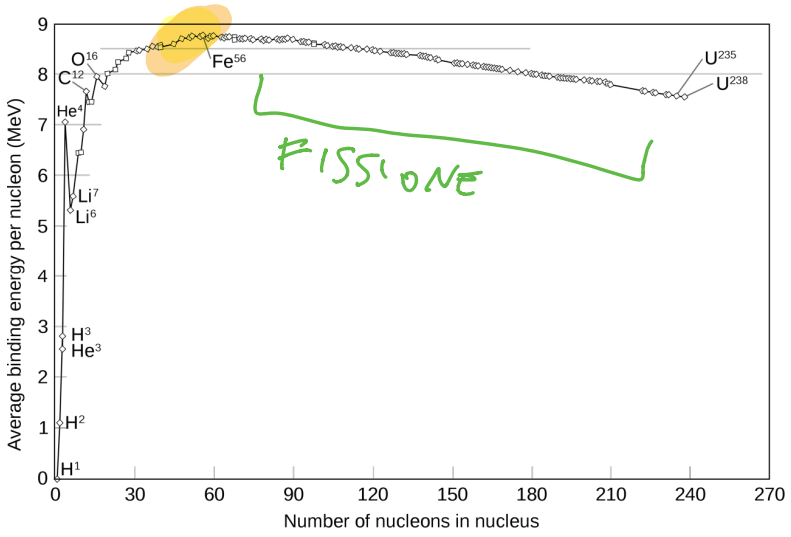
$$E_L(A,Z) = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(A-2Z)^2}{A} \pm a_5 A^{-3/4}$$

$a_5 = 0$ se Adiabatica

$a_5 > 0$ per ODD ODD

$a_5 < 0$ per EVEN EVEN

$\frac{E_L}{A}$



$${}^{A}_{Z}X \rightarrow {}^{a}_{z}Y + {}^{A-a}_{Z-z}N$$

FISSIONE SPONTANEA

$n + X \rightarrow$ si osserva un decadimento β^-

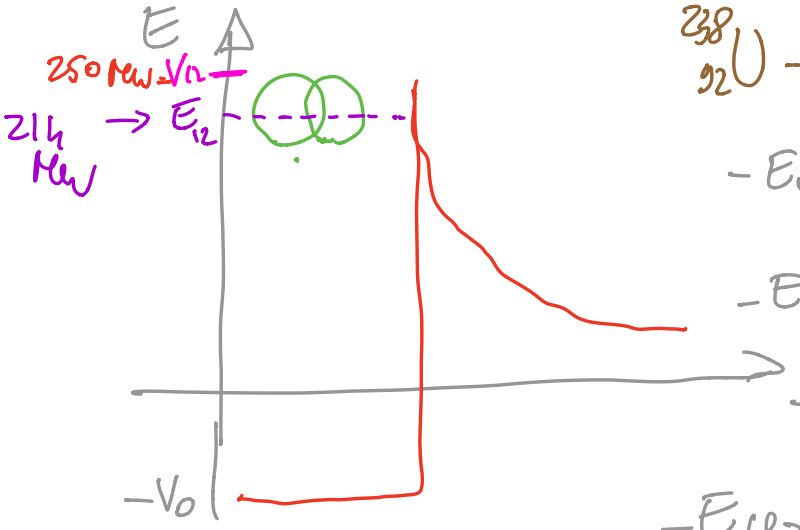
^{238}U

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

FISSIONE: competizione

- forza nucleare: $E_L \propto A$
- forza EM: $E_L \propto -Z^2$

$|i\rangle$ $|f\rangle$



$^{238}_{92}U \rightarrow {}^{119}_{46}Pd + {}^{119}_{46}Pd$

$-E_L(238,92) = -238 \cdot 7.6\,MeV$
$= -1809\,MeV$

$-E_L(119,46) = -119 \cdot 8.5\,MeV$

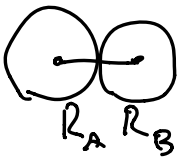
$-E_{|f\rangle} = 2\,E_L(119,46)$
$= -2033\,MeV$

$\rho \propto \rho(E=Q)$

$A \rightarrow B + C$

$$V_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{z_B \cdot z_C \cdot e^2}{r_{12}}$$

$r_{12} = ?$



$r_{12} = R_A + R_B$

$= 2R_{Pd}$

$= 2R_0 \cdot A_{Pd}^{1/3} \approx 6\,fm$

$$V_{12} = \left(\frac{e^2}{4\pi\varepsilon_0}\right)\frac{(46)^2}{6\,fm} = (\hbar c)\,\frac{(46)^2}{6\,fm}$$

$$\simeq \left(\frac{1}{137}\cdot 197\,MeV/fm\right)\frac{46^2}{6\,fm} \simeq 250\,MeV$$

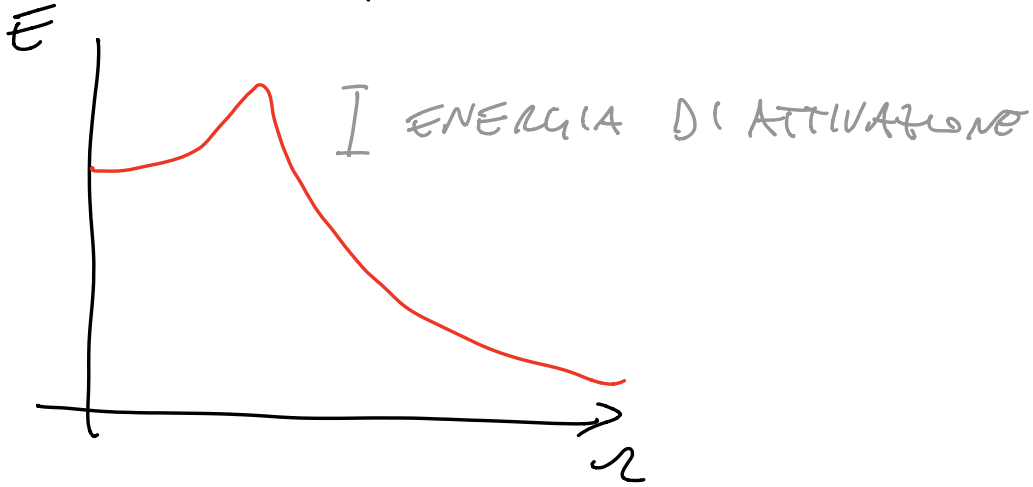
TUNNEL?

$$t_{1/2}(^{238}U) \simeq 4\cdot 10^9\,y$$

$\sim 100\%$: α decay

1 fissione ogni 10^{16} y

in miglior approssimazione



COME CAPISCO QUANTO LA FISS. SPONTANEA È PROBABILE?

la "sfera" diventa un ellissoide

$= a$

$= b$

$$\mathcal{V} = \frac{4}{3}\pi a b^2$$

sfera originale

$$a = R(1+\varepsilon)$$

Voglio una deformazione a $\mathcal{V}$ costante

$$b = R \times \frac{1}{\sqrt{1+\varepsilon}}$$

$$E_L(A, Z) \rightarrow E_L(A, Z, \varepsilon)$$

- $S = 4\pi R^2 \left(1 + \frac{2}{5}\varepsilon^2 + \dots\right)$

$$-a_2 A^{2/3} \xrightarrow{\varepsilon} -a_2 A^{2/3}\left(1+\frac{2}{5}\varepsilon^2\right)$$

- forza EM:

$$U = \frac{1}{2}\iint \frac{1}{4\pi\varepsilon_0}\frac{\rho(r_1)\,dr_1\,\rho(r_2)\,dr_2}{r_{12}}$$

$$= U_{sfera} \times \left(1 - \frac{\varepsilon^2}{5} + \dots\right)$$

$$-a_3 \frac{Z^2}{A^{1/3}} \xrightarrow{\varepsilon} -a_3 \frac{Z^2}{A^{1/3}}\left(1-\frac{\varepsilon^2}{5}\right)$$

$$E_L(A,Z,\varepsilon) - E_L(A,Z)$$

$$= \frac{2}{5}\varepsilon^2 a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}}\frac{\varepsilon^2}{5}$$

$$\equiv \Delta E$$

$$= \frac{2}{5}\varepsilon^2 a_2 A^{2/3}\left(1 - \frac{a_3}{2a_2}\frac{Z^2}{A}\right)$$

$$a_3 \simeq 0.7\ \text{MeV}$$

$$a_2 \simeq 17\ \text{MeV}$$

significa che il nuclide A(A,Z) è più stabile dello stato B+C se

$$\frac{Z^2}{A} < 50$$

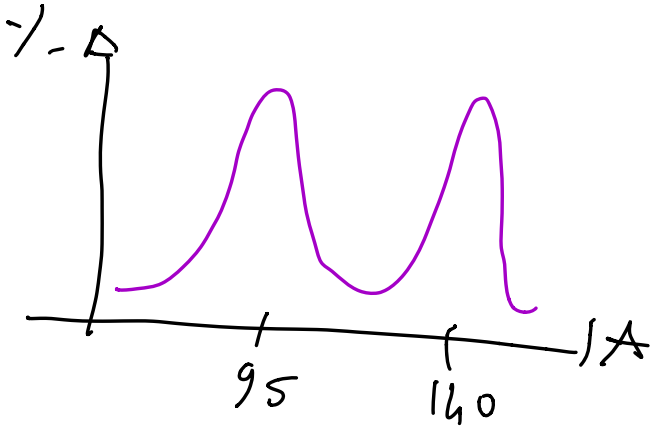
FISSIONE INDOTTA

(ES) $n + {}^{235}_{92}U \longrightarrow {}^{93}Rb + {}^{141}Cs + 2n$

0.7% dell'uranio

$T_n \simeq 25\ meV = kT$

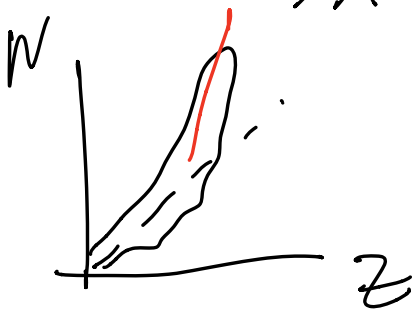
↳ TEMPERATURA



EMISSIONE ISTANTANEA (PROMPT) $\bar{\nu} \simeq 2.5\ n$

Poi $^{95}_{37}Rb_{58}$ $^{140}_{55}Cs_{85}$

$Z/A \sim 0.39$



MA GLI STABILI HANNO (per quel valore di A)

$Z/A \sim 0.41$

→ EMETTERANNO n (tempi ~ s)

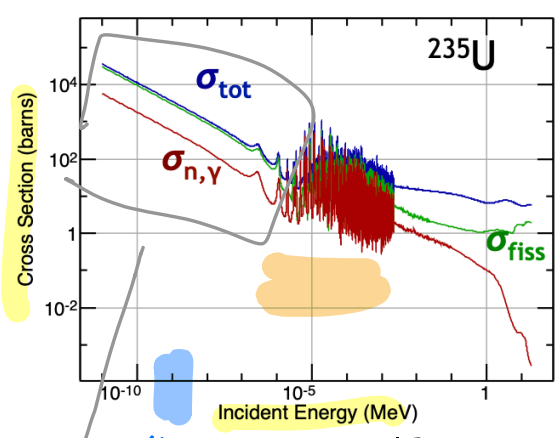
Poi $^{93}_{37}Rb \xrightarrow{6s} {}^{93}Sr \xrightarrow{7\,min} {}^{93}Y \xrightarrow{10\,h} Zr$

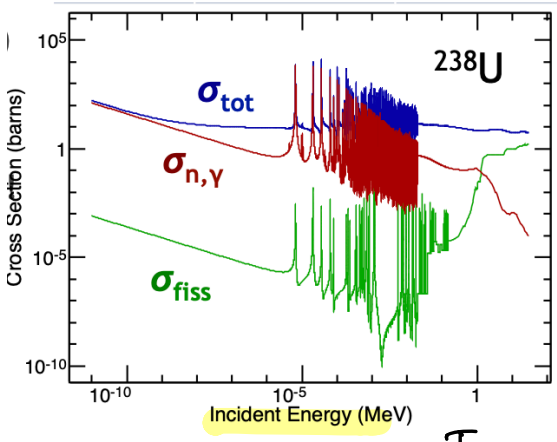
$\xrightarrow{10^6\,y} {}^{93}_{41}Nb$

→ WASTE (β^-)

$n + {}^{238}U \longrightarrow$ qualcosa

$n + {}^{235}U \longrightarrow$ qualcos'altro





T_n T_n

n TERMICI ($T_n \sim K\theta_{amb} = 25\,meV$)

$\sigma_{n,\gamma}$: $n + p \rightarrow d + \gamma$

$n + p \rightarrow {}^2H + \gamma$

$\sigma \propto \frac{1}{v}$ $\quad \sigma \simeq \pi (R + \lambda_n)^2$

$\lambda_n \simeq \lambda = \frac{h}{mv}$

RISONANZE

stati di eccitaz. "n-U"

DIFF BW - (VERDE + ROSSO): interaz. fra n. e U elastiche / anelastiche

$n + {}^{235}U \rightarrow {}^{236}U^* \rightarrow \dots$

$E_{EXCITATION} = M({}^{236}U^*) - M({}^{236}U)$

$= 6.5$ MeV

$E_{ATTIVAZ} = 6.2$ MeV

$\rightarrow$ basta T_n piccolo

$n + {}^{238}U \rightarrow {}^{239}U^*$

$E_{EXCITATION} = 4.8$ MeV
$E_{ATTIVAZ} = 6.6$ MeV
] serve $T_n \sim 2$ MeV

${}^{236}U$ ha 92 p $\rightarrow$ EVEN-EVEN

${}^{239}U$ $\rightarrow$ EVEN-ODD

$a_5 A^{-3/4} \rightarrow \sim 1$ MeV di differenza tra i due casi

ES $^{235}U + n \rightarrow {}^{236}U^{*} \rightarrow {}^{93}Rb + {}^{141}Cs + 2n$

$Q = 181\ MeV$

$\simeq 0.9\ MeV/nucleone$

- n prompt
- n ritardati

$$\frac{dN(t)}{N(t)} = -\lambda\, dt + \lambda dt(q\nu)$$

PROB. CHE INDUCANO UNA NUOVA FISSIONE

$\lambda = 1/\tau$ FISSIONE (PRIMARI)

$(\nu q - 1)\, t/\tau$

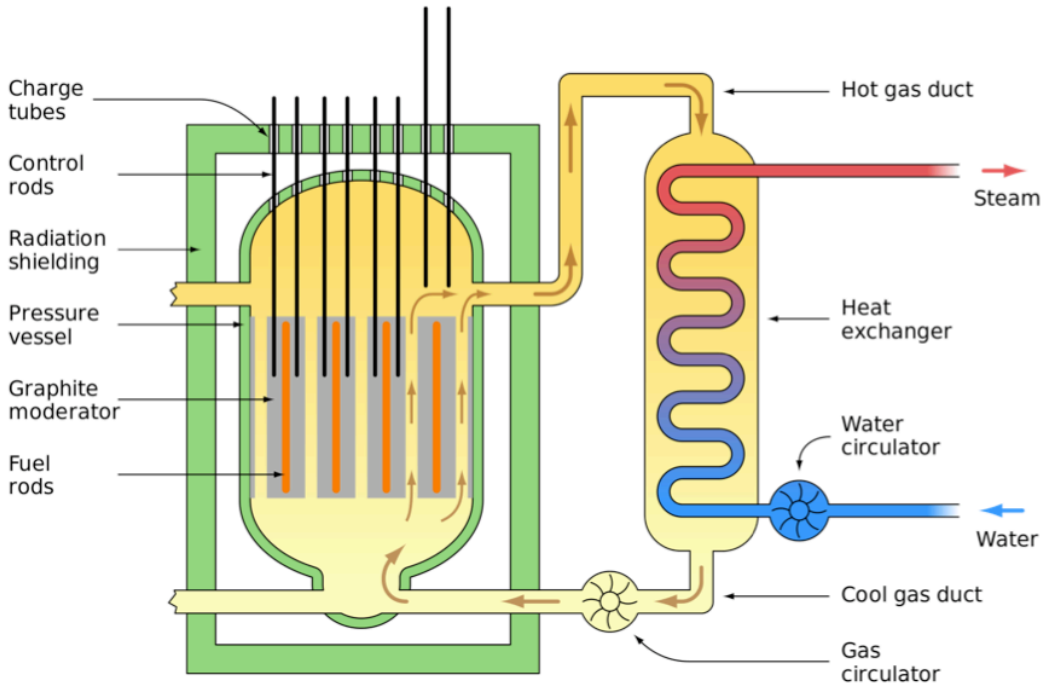
$N(t) = N(0)\, e$

$\nu q < 1$ REGIME SUB-CRITICO

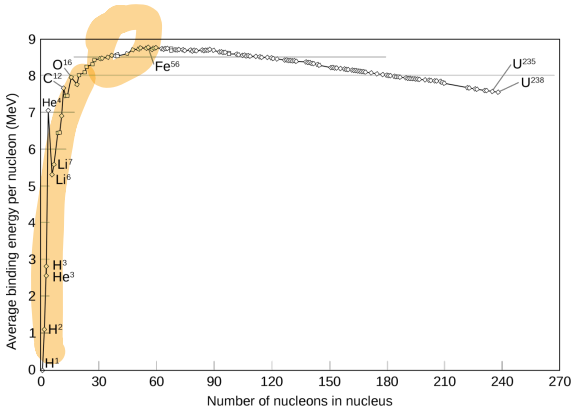
$\nu q = 1$ REGIME CRITICO

$\nu q > 1$ SUPER CRITICO

$$\eta = \frac{\sigma_{FISS}}{\sigma_{FISS} + \sigma_{n,\gamma}}$$



FUSIONE



GRAFITE (C) è un esempio di MODERATORE

→ nucleo T_n

$M_n \sim M_C$

→ URTO!

ACQUA andrebbe bene

MA:

$n + p \rightarrow d + \gamma$