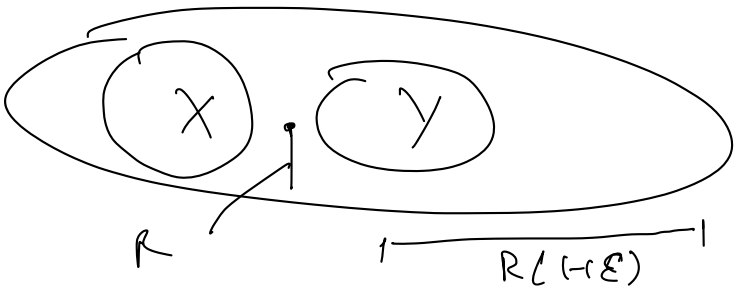
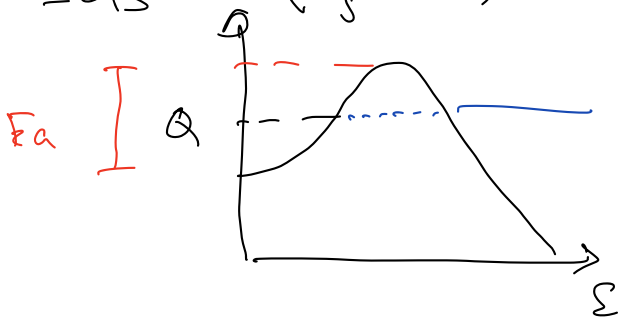
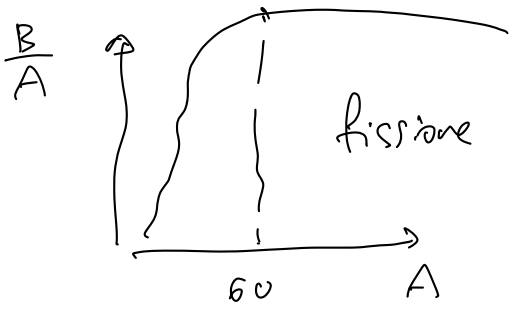
Token: 599 866



$$ {}^{A}_{Z}N \longrightarrow X + Y + Q. $$

$$ \Delta B = -a_S A^{2/3}\left(\frac{2}{5}\varepsilon^2\right) - a_C Z^2 A^{1/3}\left(-\frac{1}{5}\varepsilon^2\right) $$





pretende: $\Delta B \simeq 0$

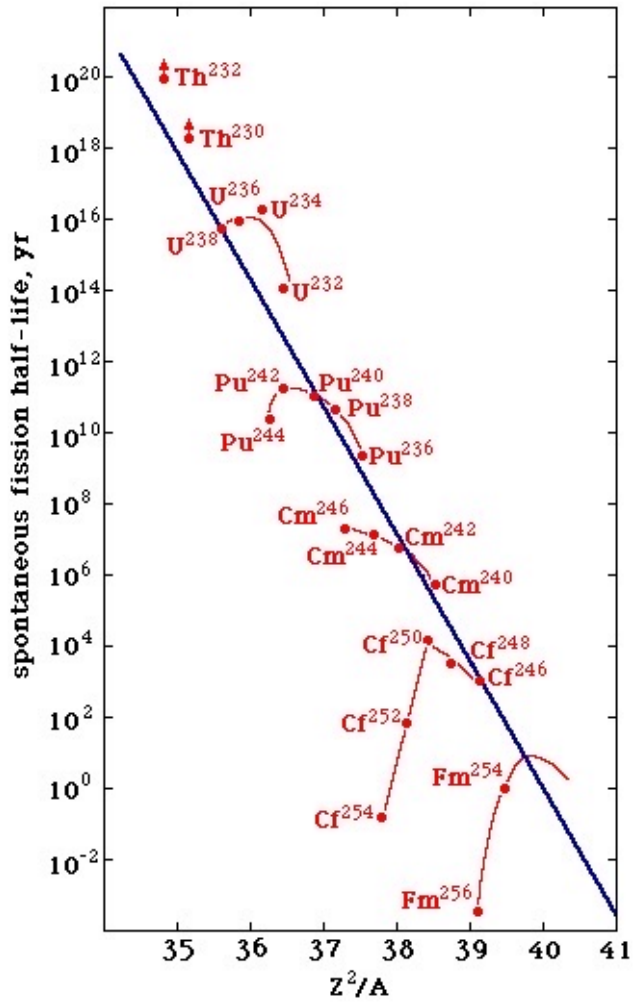
$\frac{\partial B}{\partial A} < 0$

$Q > 0 \qquad \Delta B \simeq 0 \Rightarrow A \simeq 200$

$A \simeq 300$ $Q) E_a$ spontane.

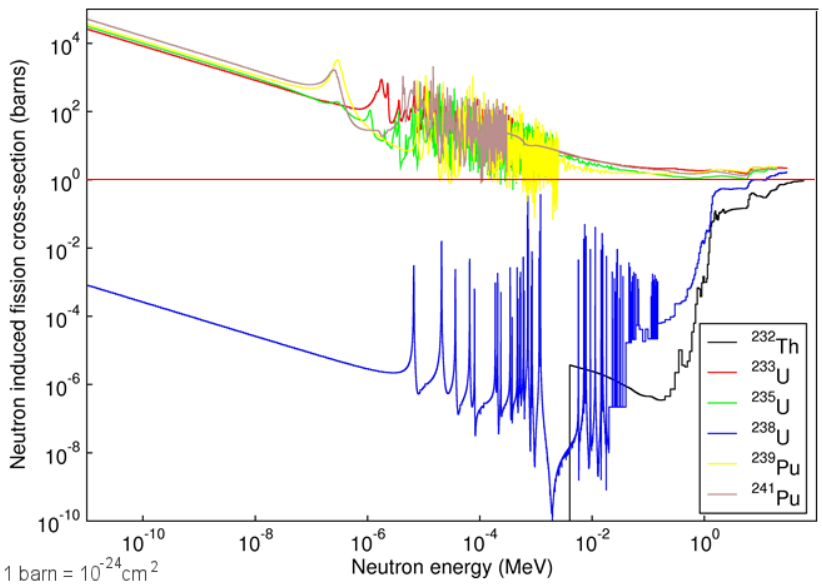
$A \simeq 200$ favorito.

$A \simeq 60$ $E_a - Q \simeq 60$ MeV improbabile



$T_{1/2}$

$N \longrightarrow X + Y$



$n + N \longrightarrow N' + Q$

$^{238}_{92}U$ 99.3%

$^{235}_{92}U$ 0.7%

$Q = 4.8$ MeV $E_a = 6.6$ MeV

$Q = 6.5$ MeV $E_a = 6.2$ MeV

$\sigma(n + {}^{238}U \rightarrow {}^{239}U^{*}) \simeq 0.5\ b$ $\quad K_n \simeq 1.8\ MeV$

$\sigma(n + {}^{235}U \rightarrow {}^{236}U^{*}) \simeq 580\ b$ $\quad K_n \simeq 0.025\ eV$

$$n + {}^{235}_{92}U \longrightarrow \begin{cases} {}^{87}_{35}Br + {}^{146}_{57}La + n \\ {}^{93}_{37}Rb + {}^{141}_{55}Cs + 2n \\ {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3n \end{cases}$$

in media $\langle \#n \rangle \simeq 2.5$ $\quad Q \simeq 200\ MeV$

$$n = \frac{Q}{M} \simeq \frac{200\ MeV}{220\ GeV} \simeq 10^{-3}$$

1g di cranio

$$Q = \frac{1}{235} \times 6 \times 10^{23} \times 200\ MeV = 5 \times 10^{23}\ MeV$$

$\simeq 10^{11}\ J$ $\quad \simeq \times 3$ en. prodotta dalla combustione di 1T di carbone

$n + X \longrightarrow n' + X$

$E_n' < E_n$

$n + H_2O \longrightarrow$ urti tra n e p

D_2O $\quad {}^{2}_{1}H$ $\quad$ ottimo assorbitore.

acqua pesante

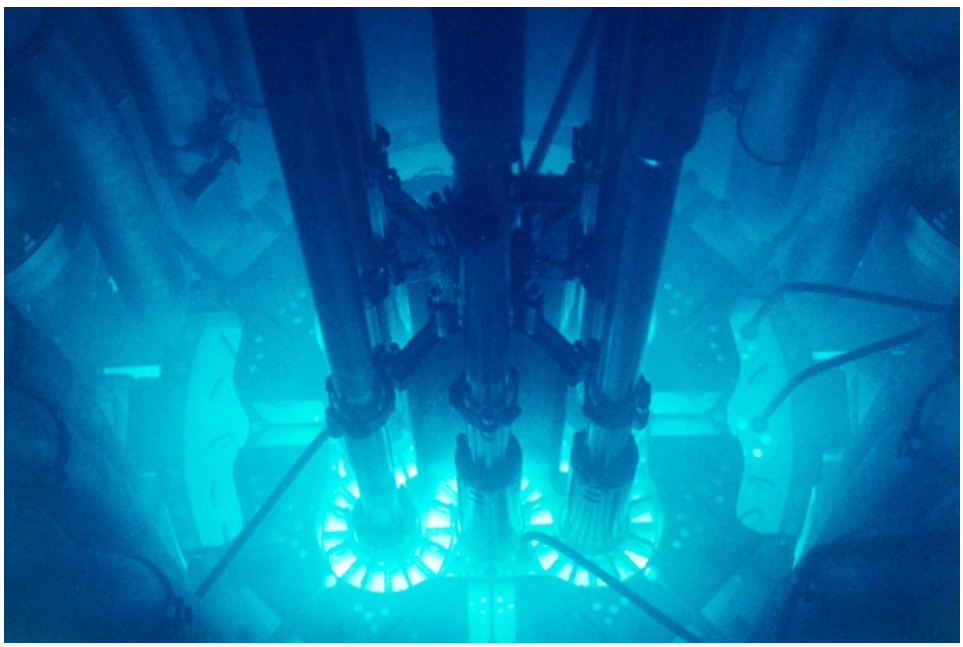
$n + {}^{2}_{1}H \longrightarrow {}^{3}_{1}H \longrightarrow {}^{3}_{2}He + e^- + \nu_e$

18 KeV

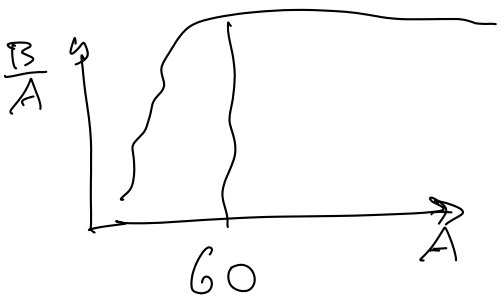
tritio

$T_{1/2} \simeq 12\ yr$

$n + {}^{2}_{1}H \longrightarrow {}^{3}_{1}H^{*} \longrightarrow {}^{3}_{1}H + \gamma$



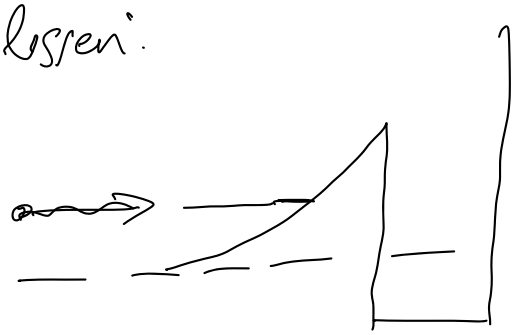
Fusione nucleare

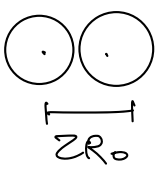


${}^{a}_{z}X + {}^{b}_{w}Y \longrightarrow {}^{a+b}_{z+w}N + Q$

$\frac{\partial B}{\partial A} > 0$ Vantaggio per nuclei leggeri.

$p + p \longrightarrow$





$U(2R) = \frac{e^2}{4\pi\varepsilon_0} \frac{1}{2R_0} \simeq \frac{\alpha}{2} \frac{1}{R_0}$

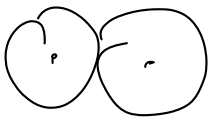
$R_0 \simeq 1$ fm 200 MeV fm $= 1 \Rightarrow 1\ \text{fm}^{-1} \simeq 200$ MeV

$U(2R) \simeq 550$ keV Ener. cin. minime dei protoni per fare fusione.

$$^{12}_{6}C + ^{12}_{6}C \longrightarrow ^{24}_{12}Mg$$

magnesio

$$Q = 2M_C - M_{Mg} = 13.9 \text{ MeV}$$

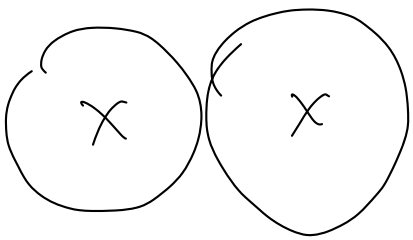


$$2R = 2R_0 A^{1/3}$$

$U(2R) \simeq 9$ MeV

$Q' = 13.9 - 9 \simeq 5$ MeV netto

$$\eta = \frac{Q'}{2Mc} = \frac{5 \text{ MeV}}{2 \times 11 \text{ GeV}} \simeq 10^{-4}$$



$$^{A}_{Z}X + ^{A}_{Z}X \longrightarrow N + Q$$

$$U(R) = \frac{e^2}{4\pi\varepsilon_0} \frac{Z^2}{2R}$$

$$= \frac{e^2}{4\pi\varepsilon_0} \frac{Z^2}{2R_0 A^{1/3}} = \frac{\alpha}{2R_0} \frac{Z^2}{A^{1/3}}$$

$\frac{Z}{A} \simeq \frac{1}{2}$ $Z = \frac{A}{2}$ $\Rightarrow$ $U(R) \propto \frac{A^2}{A^{1/3}} \propto A^{5/3}$

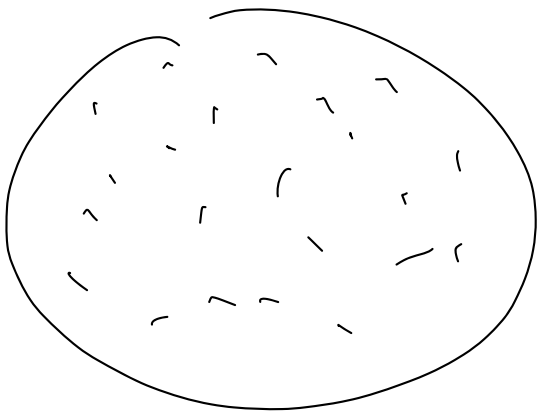
$$U(R) = (0.145\ MeV)\ A^{5/3}$$

Nucleo $A=4, Z=2 \Rightarrow A^{5/3} \simeq 10 \Rightarrow U \simeq 1.45\ MeV$

Un gas di nuclei di massa $M(Z,A)$

$KT = 145\ keV \qquad K = 8.6 \times 10^{-5}\ eV\ K^{-1}$

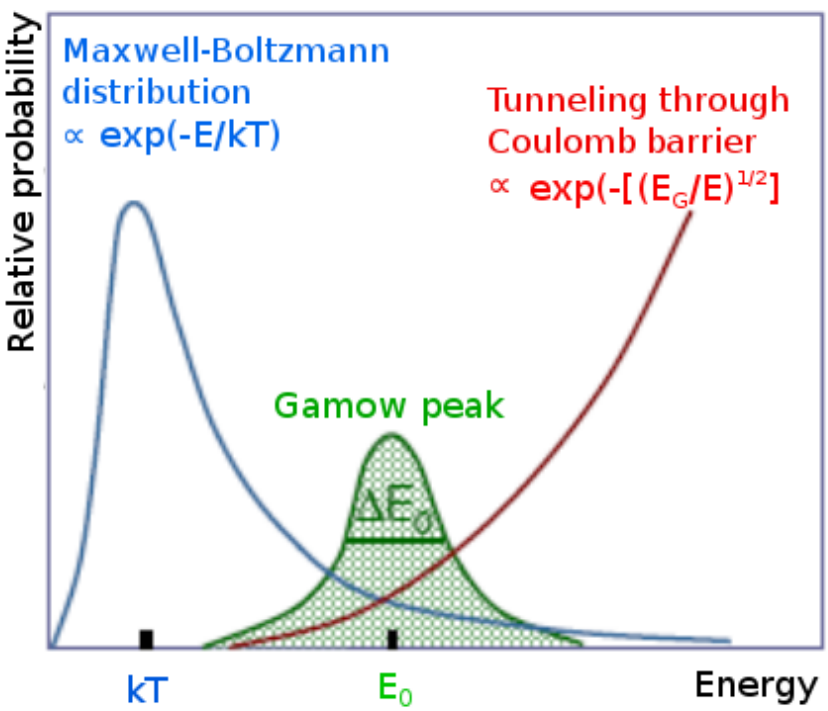
$\Rightarrow T = 1.6 \times 10^{9}\ K$



$$\langle E \rangle = \frac{3}{2} KT = \frac{1}{2} m \bar{v}^2$$

$$\frac{dN}{dv} = \frac{v^2}{(2KT/m)^{3/2}}\, e^{-\frac{1}{2}\frac{mv^2}{KT}}$$

$$\bar{v} = \sqrt{\frac{3KT}{m}}$$



Fusione nelle stelle

$p+p+p+p \longrightarrow {}^4He + 26\ MeV$ energia.

$$\eta = \frac{26\ MeV}{3750\ MeV} = 7 \times 10^{-3}$$

$T_{Sole}^{int} = 1.5 \times 10^7\ K \Rightarrow \bar{E} = \frac{3}{2}kT = 190\ keV$

fusione possibile grazie a Eff. tunnel e picco di Gamow.

1) $p + p \longrightarrow {}^2_1H + e^+ + \nu_e \quad Q = 0.42\ MeV$

B	1	1	2	0	0
Le	0	0	0	-1	+1
Q	+1	+1	+1	+1	0

processo med. de int debole $\sigma \sim 10^{-55}\ cm^2$

$\sigma \sim 10^{-31}\ b \qquad \tau_{SS} \simeq 5 \times 10^9\ yr$

2) $p + {}^2_1H \longrightarrow {}^3_2He + \gamma \quad Q = 5.49$

(${}^2_1H$: deuterio; ${}^3_2He$: instabile)

3) ${}^3_2He + {}^3_2He \rightarrow {}^4_2He + p + p \quad Q = 12.86\ MeV$

$3p + 3p \longrightarrow {}^4_2He + 2p + 2e^+ + 2\nu + 2\gamma$

$4p$

$Q = 4m_p - m_\alpha - 2m_e - 2m_\nu$

$\simeq 24.7\ MeV$

$\langle E_\nu \rangle \simeq 0.3$ MeV

$Q' = Q - 2 E_\nu \simeq 24$ MeV.

$e^+ + e^- \longrightarrow 2\gamma$

Ciascun positrone produce 2 γ con $E \simeq 1$ MeV.

$Q_{uscito} = Q - 2E_\nu + \underbrace{2 \times 1\,\text{MeV}}_{e^+} = 26$ MeV

$\eta = 0.007$ rendimento.

processo debole

$p + p \rightarrow {}^2H + e^- + \nu_e$ 99.77%

$p + p + e^- \rightarrow {}^2H + \nu_e + 0.42\,MeV$ 0.23%

$^2H + p \rightarrow {}^3He + \gamma + 5.49\,MeV$

$^3He + {}^3He \rightarrow \alpha + 2p + 12.86\,MeV$ 84.92%

$^3He + p \rightarrow \alpha + e^+ + \nu_e$ $\approx 10^{-5}$%

$^3He + \alpha \rightarrow {}^7Be + \gamma + 1.59\,MeV$ 15.08%

Nucleosintesi:

Si produce ${}^4_2He$ finché protoni esaurisconо.

${}^4_2He + {}^4_2He \longrightarrow {}^8_4Be$ $Q = -0.099$ MeV instabile

${}^8_4Be \rightarrow {}^4_2He + {}^4_2He$ $\tau \simeq 0.7 \times 10^{-16}$ s

${}^4_2He + {}^8_4Be \longrightarrow {}^{12}_6C^* \longrightarrow {}^{12}_6C + \gamma$

$$^4_2He + {}^{12}_6C \longrightarrow {}^{16}_8O + \gamma \qquad Q = 7.16\ MeV$$

$$^4_2He + {}^{16}_8O \longrightarrow {}^{20}_{10}Ne + \gamma \qquad Q = 4.73\ MeV$$

$$^4_2He + {}^{20}_{4}Ne \longrightarrow {}^{24}_{12}Mg + \gamma \qquad 9.31\ MeV$$

^4_2He esaurito $\Rightarrow$ collasso $\Rightarrow$ T aumenta ulteriormente.

$$^{12}_6C + {}^{12}_6C \longrightarrow {}^{20}_{10}Ne + {}^4_2He$$

$^{20}_{10}Ne$ / $^{24}_{12}Mg$ / $^{28}_{14}Si$

Si ferma per $\frac{\partial B}{\partial A} \simeq 0 \Rightarrow A \simeq 56$

1) Cattura neutronica.

2) $M > 1.5\ M_\odot$