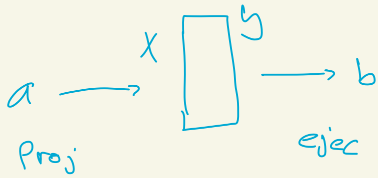
$$a + X \longrightarrow y + b$$

$$X\,(a, b)\,y$$



p α

$${}^{1}_{1}H + {}^{7}_{3}Li \longrightarrow {}^{4}_{2}He + {}^{4}_{2}He$$

$${}^{7}_{3}Li\,(p, \alpha)\,{}^{4}_{2}He$$

$$\underset{\text{befor}}{A} = \underset{\text{after}}{A}$$

but the p or n are not conserved

Charge is conserved

$$q = q$$

Conservation of Energy, p, L

total E_{before} = total E_{after}

$$K_a + M_a c^2 + M_x c^2 = M_y c^2 + K_y + M_b c^2 + K_b$$

$$K_y + K_b - K_a = (M_a + M_x - M_y - M_b)\, c^2$$

$$= Q$$

Q
- > 0 exothermic
- < 0 endothermic
- 0 elastic scattering

$$a + x \rightarrow x + a$$

n

$$^{13}C\,(^{12}C,\ ^{13}C)\ ^{12}C$$

exchang

rxn

$$^{12}C\,(^{13}C,\ ^{13}C)\ ^{12}C$$

$Q > 0$, $K_y + K_b$ KE

$Q < 0$, $K_a > Q$

threshold

$$K_a = -Q\left[1 + \frac{M_a}{M_x}\right] > 0$$

endothermic

Table 14.1 ***Q* Values for Nuclear Reactions Involving Light Nuclei**

Reaction[a]	Measured Q Value (MeV)
^{2}H(n, γ)^{3}H	6.257 ± 0.004
^{2}H(d, p)^{3}H	4.032 ± 0.004
^{6}Li(p, α)^{3}H	4.016 ± 0.005
^{6}Li(d, p)^{7}Li	5.020 ± 0.006
^{7}Li(p, n)^{7}Be	-1.645 ± 0.001
^{7}Li(p, α)^{4}He	17.337 ± 0.007
^{9}Be(n, γ)^{10}Be	6.810 ± 0.006
^{9}Be(γ, n)^{8}Be	-1.666 ± 0.002
^{9}Be(d, p)^{10}Be	4.585 ± 0.005
^{9}Be(p, α)^{6}Li	2.132 ± 0.006
^{10}B(n, α)^{7}Li	2.793 ± 0.003
^{10}B(p, α)^{7}Be	1.148 ± 0.003
^{12}C(n, γ)^{13}C	4.948 ± 0.004
^{13}C(p, n)^{13}N	-3.003 ± 0.002
^{14}N(n, p)^{14}C	0.627 ± 0.001
^{14}N(n, γ)^{15}N	10.833 ± 0.007
^{18}O(p, n)^{18}F	-2.453 ± 0.002
^{19}F(p, α)^{16}O	-8.124 ± 0.007

[a]The symbols n, p, d, α, and γ denote the neutron, proton, deuteron, alpha particle, and photon, respectively. From C. W. Li, W. Whaling, W. A. Fowler, and C. C. Lauritsen, *Phy. Rev.,* 83:512, 1951.

cross section area

$\sigma = \pi r^2$

barn $= 10^{-28}$ m

$\sigma = \pi r_0^2 A^{2/3}$

lowing notation:

current

R_0 = Rate at which incident particles strike the foil (particles/s)

R = Rate at which reaction events occur (reactions/s) new • after rxn

n = Number of target nuclei per unit volume (particles/m^3)

number of the atoms

surface area for the nucleus

$$\frac{R}{R_0} = \frac{N\sigma}{A} = \frac{\frac{N}{V} V \sigma}{A} = \frac{n \sigma A x}{A} = \sigma n x$$

surface area for the target

$$\boxed{\frac{R}{R_0} = \sigma n x}$$

number of every particles

number of incident particles

$$-\frac{dN}{N} = \sigma n \, dx$$

$$\ln \frac{N}{N_0} = -\sigma n x \rightarrow \boxed{N = N_0 e^{-\sigma n x}}$$

$$\bar{\nu} + p \longrightarrow e^+ + n \qquad (\sigma = 10^{-19}\ \text{b})$$

Weak interaction

inelastic

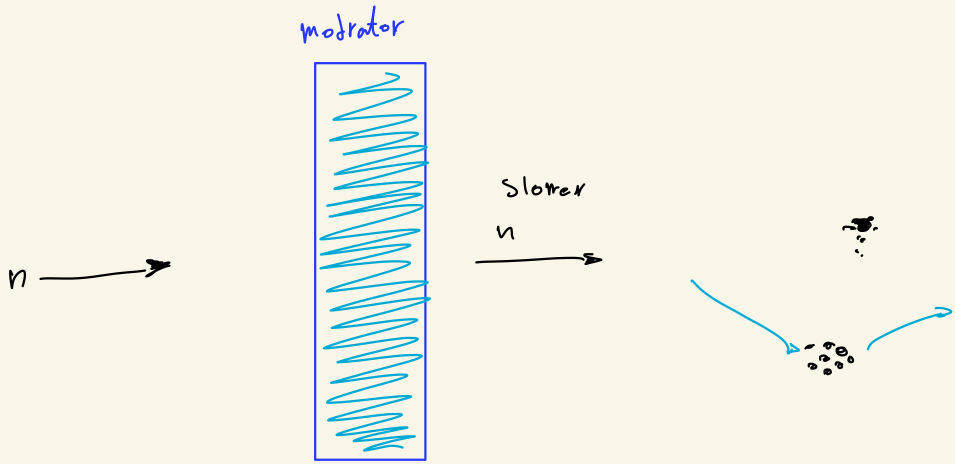
$$n + {}^{127}I \longrightarrow {}^{127}I^* + n \qquad (\sigma = 4\ \text{b})$$
$$n + {}^{129}Xe \longrightarrow {}^{129}Xe^* + n \qquad (\sigma = 4\ \text{b})$$

Stron interaction

---

1 particle = 1.602×10^{-19} C

$$n_{free} \xrightarrow{T_{1/2}\ \text{ionic}} p + e^- + \bar{\nu}$$



$$n + {}^{A}_{Z}X_{N} \longrightarrow {}^{A+1}_{Z}X_{N+1} + \gamma$$ neutron capture

converting X to isotops

fast → inelastic

slow → thermal → isotpes

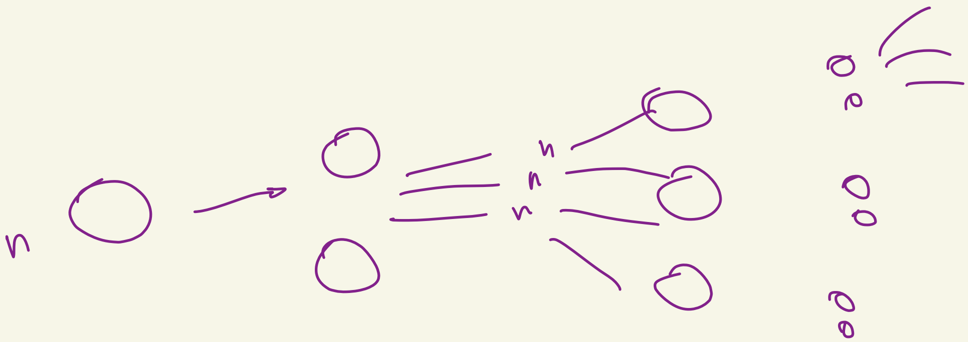
$^{235}_{92}U$ $\quad T_{1/2} = 7.04 \times 10^{8}$ yr

very rare

0.72%

100% α - emitter

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U^{*} \rightarrow X + Y + \text{neutrons}$$



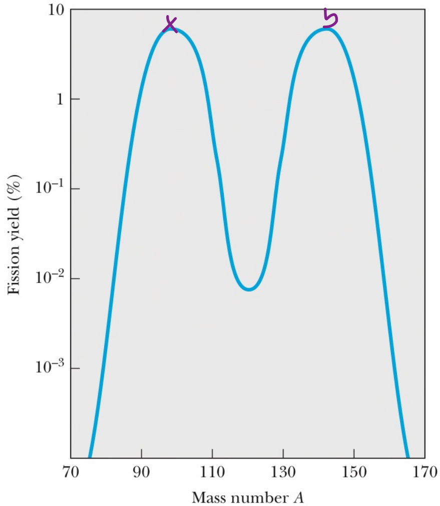


Figure 14.4 The distribution of fission products versus mass number for the fission of ^{235}U bombarded with slow neutrons. Note that the ordinate has a logarithmic scale.

$$ {}^{1}_{0}n + {}^{235}_{92}U \xrightarrow[\text{weakly bound}]{{}^{236}U^{*}} \overbrace{{}^{141}_{56}\underline{Ba} + {}^{92}_{36}\underline{Kr}}^{\text{fragments}} + 3\,{}^{1}_{0}n $$

strong bonded

$Q = 200$

fission $\longrightarrow$ 2.5 n

$\downarrow$

avg

Prompt $n \longrightarrow$ fast

Self - sustained

chain reaction

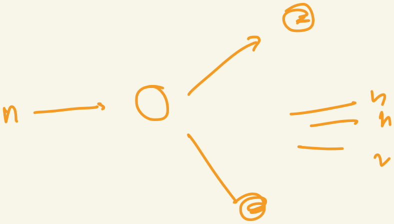
reproduction constant K, number of n

$K = 1 \longrightarrow$ critical

$K < 1 \longrightarrow$ subcritical, dies out

$K > 1 \longrightarrow$ supercritical

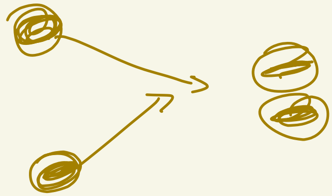
fission



nuclear waste

U !

fusion



no nucler waste

more Energy than fission

$$X + y \longrightarrow Z + \gamma$$

H H He

up to 5G

$$
\begin{aligned}
{}^1_1\mathrm{H} + {}^1_1\mathrm{H} &\longrightarrow {}^2_1\mathrm{H} + {}^0_1\mathrm{e}^+ + \nu \\
{}^1_1\mathrm{H} + {}^2_1\mathrm{H} &\longrightarrow {}^3_2\mathrm{He} + \gamma
\end{aligned}
$$

$$
\begin{aligned}
{}^1_1\mathrm{H} + {}^3_2\mathrm{H} &\longrightarrow {}^4_2\mathrm{He} + {}^0_1\mathrm{e}^+ + \nu \\
{}^3_2\mathrm{He} + {}^3_2\mathrm{He} &\longrightarrow {}^4_2\mathrm{He} + {}^1_1\mathrm{H} + {}^1_1\mathrm{H}
\end{aligned}
$$

Proton - Proton cycle $\longrightarrow$ Sun

$\boxed{\text{T should be 15MK}}$

Reactors :

$$
\begin{aligned}
{}^2_1\mathrm{H} + {}^2_1\mathrm{H} &\longrightarrow {}^3_2\mathrm{He} + {}^1_0\mathrm{n} && Q = 3.27\ \mathrm{MeV} \\
{}^2_1\mathrm{H} + {}^2_1\mathrm{H} &\longrightarrow {}^3_1\mathrm{H} + {}^1_1\mathrm{H} && Q = 4.03\ \mathrm{MeV} \\
{}^2_1\mathrm{H} + {}^3_1\mathrm{H} &\longrightarrow {}^4_2\mathrm{He} + {}^1_0\mathrm{n} && Q = 17.59\ \mathrm{MeV}
\end{aligned}
$$

✓ best

D-T reaction

what you need is:

1) Heat $T \sim 10^8$ K

2) Pressure, to incresea the Prob of hitting

3) high number of atoms

4) Heat and Pressure should stay long time

$\downarrow$ τ

$n = \frac{N}{V}$

$n^2 \tau >> n$

$n \tau \geq 10^{20} \frac{s}{m^3}$ to have high output

Lawson's Certein

Magnetic confinement:

Magnetic field to squeeze to the center

tokamak $\Longrightarrow$ squzzing

breakeven ⟶ output = input

ignition output > input

inertial confinement

Lazers hits the bullet

Lazer will not hit at the same time

$${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}H + {}^{1}n \qquad Q = 17.6\,MeV$$

α