Beta decay

β^- : $^{A}_{Z}X \rightarrow {}^{A}_{Z+1}D + \beta^- + \bar{\nu}_e$

$\bar{\nu}_e$: anti-neutrino

$$Q = [M(^{A}_{Z}X) - M(^{A}_{Z+1}D)]c^2$$

example : $n \rightarrow p + \beta^- + \bar{\nu}_e$ ($\beta^- = e^-$)

$\tau = 885\,s$

$T_{1/2} = 613\,s$

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

β^+ : $^{A}_{Z}X_N \rightarrow {}^{A}_{Z-1}D + \beta^+ + \nu_e$

$$Q = [M(^{A}_{Z}X_N) - M(^{A}_{Z-1}D) - 2m_e]c^2$$

$p \rightarrow n + e^+ + \nu_e$

EC : electron capture

$^{A}_{Z}X + e^- \longrightarrow {}^{A}_{Z-1}D + \nu_e$

$$Q = [M(^{A}_{Z}X) - M(^{A}_{Z-1}D)]c^2$$

$p + e^- \longrightarrow n + \nu_e$

How could electron capture process occur?

⇒ For the inner shell (such as 1S) electron, its wavefunction (probability amplitude) is not zero at r=0. [$R_{n0}(r) \neq 0$]

Thus, it can be captured by the neucleus.

Table 7.1 Hydrogen Atom Radial Wave Functions

n	ℓ		$R_{n\ell}(r)$
1	0	s	$\frac{2}{(a_0)^{3/2}} e^{-r/a_0}$
2	0	s	$\left(2 - \frac{r}{a_0}\right) \frac{e^{-r/2a_0}}{(2a_0)^{3/2}}$
2	1	p	$\frac{r}{a_0} \frac{e^{-r/2a_0}}{\sqrt{3}(2a_0)^{3/2}}$
3	0	s	$\frac{1}{(a_0)^{3/2}} \frac{2}{81\sqrt{3}} \left(27 - 18\frac{r}{a_0} + 2\frac{r^2}{a_0^2}\right) e^{-r/3a_0}$
3	1	p	$\frac{1}{(a_0)^{3/2}} \frac{4}{81\sqrt{6}} \left(6 - \frac{r}{a_0}\right) \frac{r}{a_0} e^{-r/3a_0}$
3	2	d	$\frac{1}{(a_0)^{3/2}} \frac{4}{81\sqrt{30}} \frac{r^2}{a_0^2} e^{-r/3a_0}$

$R_{n0}(r) \neq 0$

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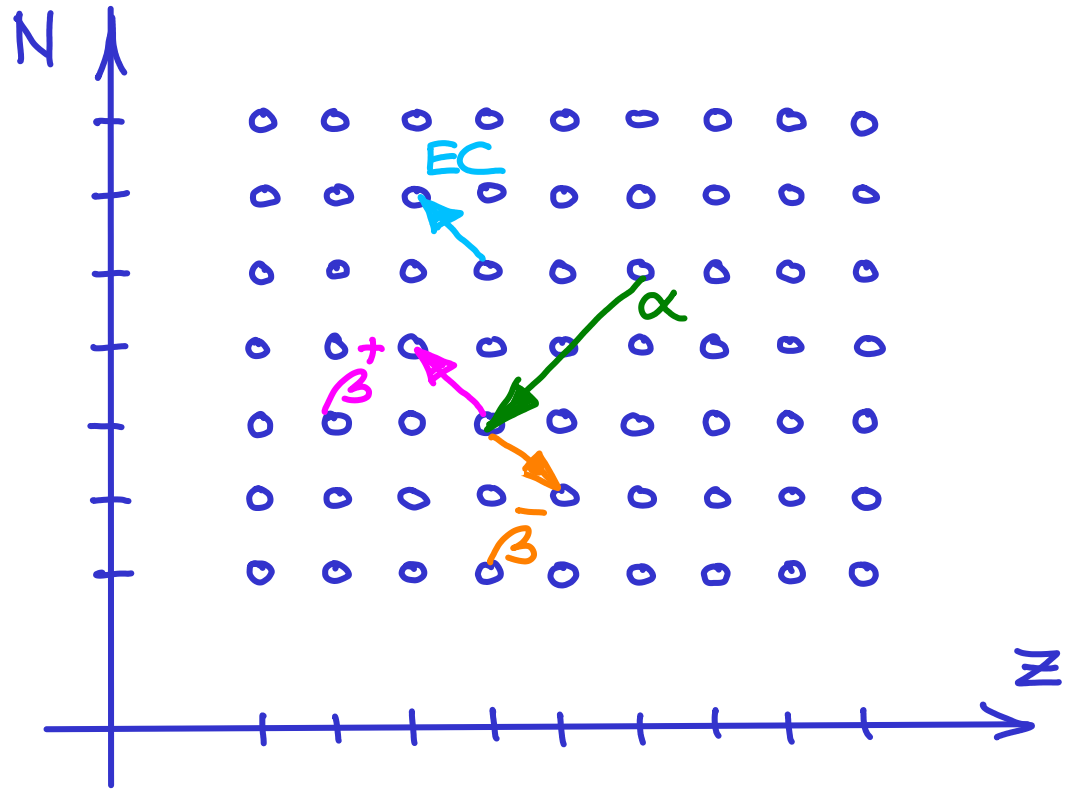
Gamma decay

$$ {}^{A}_{Z}X^{*} \longrightarrow {}^{A}_{Z}X + \gamma $$

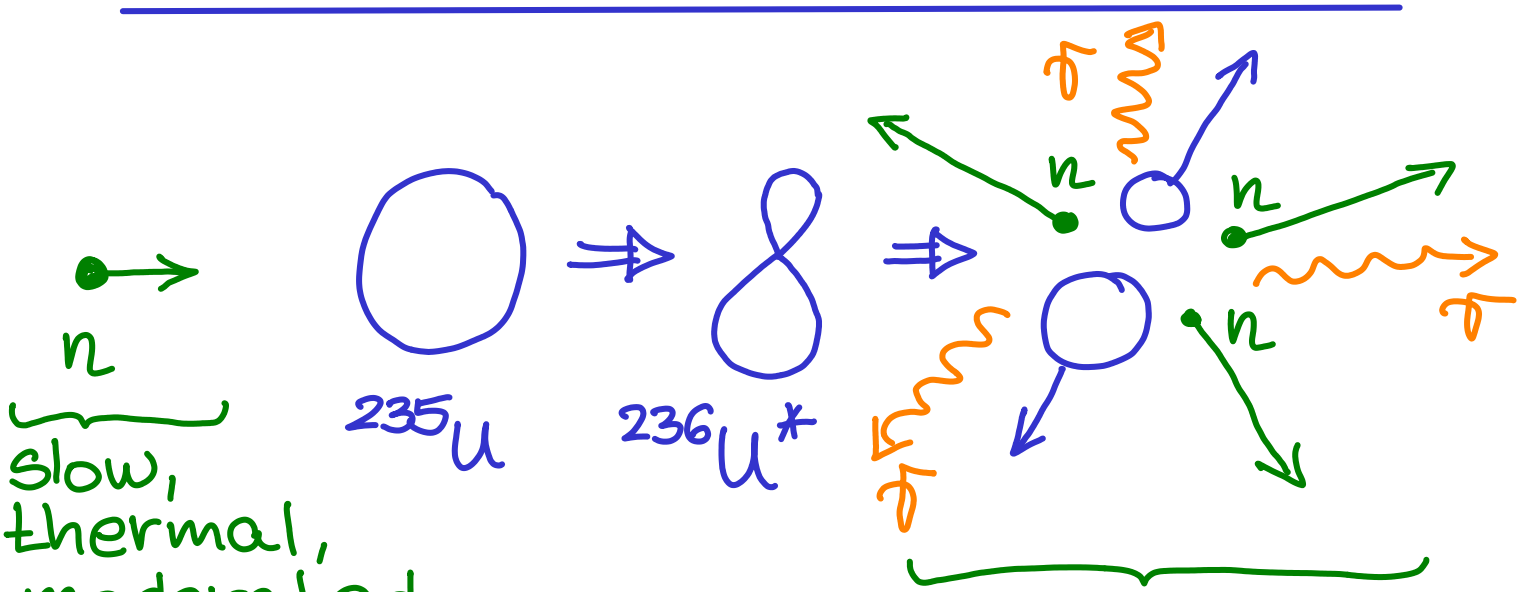
excited state

ground state or a lower excited state

spin of γ : 1 $\Rightarrow$ there are metastable states called isomers or isomeric states with half lifes of several years.



Fission and chain reaction



slow, thermal, moderated neutrons

fast neutrons (prompt, delayed)

Average energy released:

$\approx$ 200 MeV in fission
$\approx$ 20-30 MeV in later decay
$\approx$ 1% of the rest energy

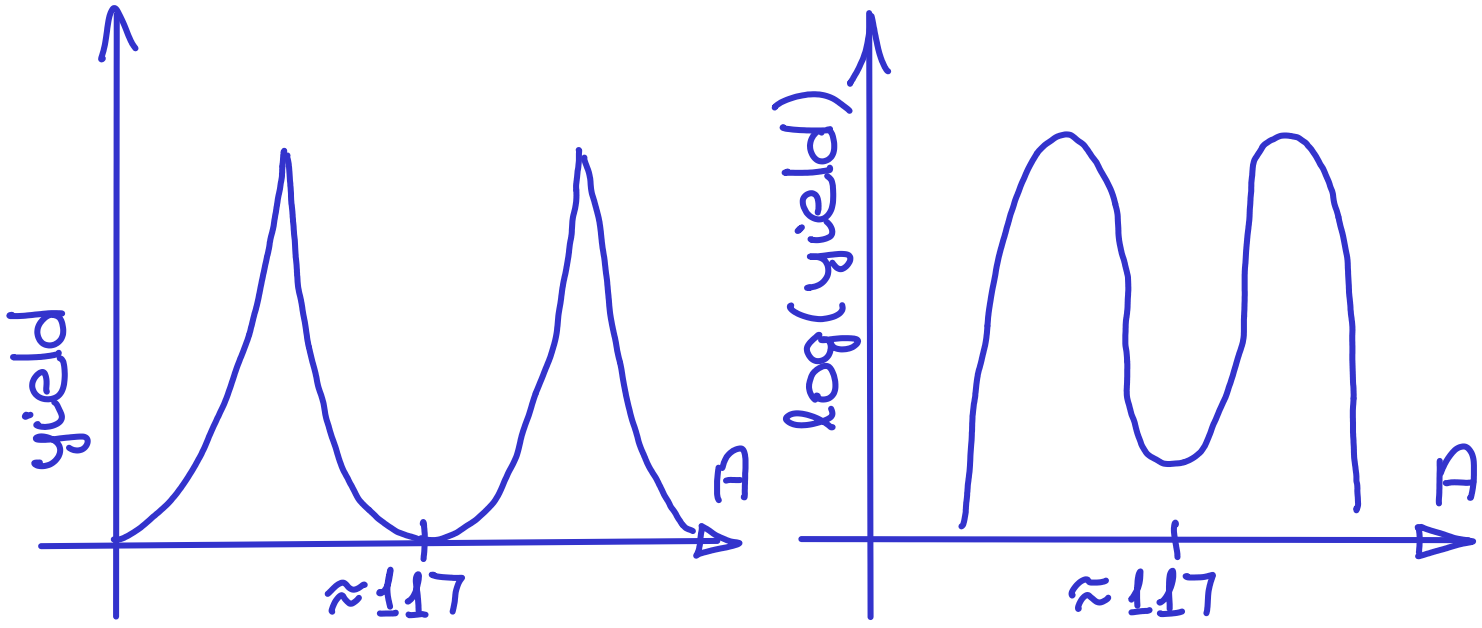
($C + O_2 \rightarrow CO_2$: 4eV $\approx \frac{1}{10,000}$ of rest en.)

Average number of neutrons released : 2.45 $\Rightarrow$ chain reaction

Fission: Otto Hahn (1944, Nobel), Fritz Strassman, Lise Meitner, Otto Frisch.

Chain reaction: Leo Szilárd

Fission fragment distribution



Fission cross section