Nuclear Structure

$^{A}_{Z}X$

Every element has symbol, A and Z

- A → mass number
- Z → atomic number (no. of protons)

mass number $= n + 3$

- n → number of neutrons
- 3 → number of protons

	$^{11}_{6}C$	$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$
neutrons	5	6	7	8

} isotopes

Isotopes are not for all elements

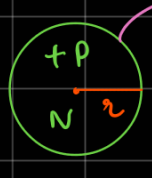
	election	proton	neutron
charge	-ve	+ve	no charge
	-1.6×10^{-19}	1.6×10^{-19}	—
	9.11×10^{-31}	1.67×10^{-27}	1.67×10^{-27}

Positron (positive election) +ve 1.6×10^{-19} $m = m_e = 9.11\times10^{-31}$

Atomic Mass Unit (u) $= 1.66\times10^{-27}$ kg

radius $= a \times A^{1/3}$ → mass number

$a = 1.2\times10^{-15}$



→ nuclear force

10^{-15} m

(exists only

In small distances

nuclear force exists between

p - p
n - n
p - n

keeps the atom from blowing apart due to repulsive force.

Atoms are stable / unstable

$Z \leq 20 \Rightarrow$ Stability condition $Z = N$

$Z > 20 \Rightarrow$ Stability condition $N > Z$

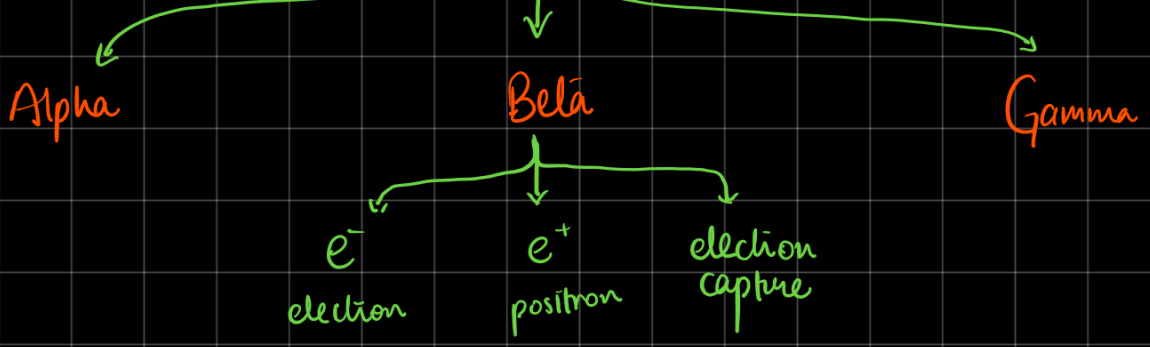
$Z > 83 \Rightarrow$ Unstable

Binding Energy → Energy that keeps particles binded together

$$E_b = [Z\,M(H) + Nm_n - M(^A_Z X)] \times 931\ MeV/c^2$$

- Z: Atomic number of element
- $M(H)$: mass of hydrogen
- N: # neutrons
- m_n: mass of neutron
- $M(^A_Z X)$: mass of element
- $[\ldots]$: in units of u

Radioactivity



$N = N_0 e^{-\lambda t}$ → λ: constant (s^{-1}); t: time

- N: # atoms after t time
- N_0: # initial atoms

Half-life → time needs to lose half of sample size

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

1000 atoms → $T_{1/2}$ → 500 → $T_{1/2}$ → 250 → 125 → ...

$R = R_0 e^{-\lambda t}$ (Bq)

- R: Activity after t time
- R_0: Initial activity

↳ Bq = 3.7×10^{10} decay / sec = 1 Ci (Curie)

$N = N_0 \left(\frac{1}{2}\right)^n$ → n: # half life times

$R = \lambda N$

$R_0 = \lambda N_0$

decay

Alpha

Radiates α particles
least powerful
can penetrate paper

Beta

e^- electron

e^+ positron

electron capture

Radiates β particles
moderately powerful
can penetrate aluminum

Gamma

Radiates γ particles
very powerful
can penetrate lead

Alpha Decay — 2 Protons, 2 Neutrons

$${}^{A}_{Z}X \xrightarrow{\text{decay}} {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

$\rightarrow$ alpha particle

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

$$\downarrow$$

$${}^{230}_{88}Y + {}^{4}_{2}He$$

Beta Decay - Electron

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \bar{e} + \bar{\nu}$$

$$n \rightarrow p + e + \bar{\nu}$$

$$\downarrow$$

$${}^{0}_{-1}e$$

$\bar{\nu}$: antineutrino, no charge, tiny mass

Beta Decay - Positron

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^+ + \nu$$

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

$$\downarrow$$

$${}^{0}_{1}e$$

ν: neutrino, no charge, tiny mass

Beta Decay - Election Capture

$${}^{A}_{Z}X + {}^{0}_{-1}e \rightarrow {}^{A}_{Z-1}Y + \nu$$ → neutrino

Gamma

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

- ${}^{A}_{Z}X^{*}$ ↓ excited state
- ${}^{A}_{Z}X$ ↓ stable / ground state

Disintegration Energy

α $\quad Q = (M_x - M_y - M_\alpha) \times 931$ MeV

M_x ↓ parent, M_y ↓ daughter, M_α ↓ alpha, u ↓ mass of

$Q > 0$ Occurs spontaneously

$Q < 0$ Cannot occur spontaneously

β^{e^-} $\quad Q = (M_x - M_y) \times 931$

β^{e^+} $\quad Q = (M_x - M_y - 2m_e) \times 931$