Nuclear Physics

Isotope	Isobar	Isotones	Isomers	Isodiaphers
Z = const	Z = variable	Z = variable	Z = const	A = variable
A = variable	A = const	A = variable	A = const	Z = variable
N_p = const.	N_p = variable	N_p = variable	$N_p = N_n$ = const,	N_p = variable
N_n = variable $= A - Z$	N_n = variable	$N_n = (A-Z)$ const	meta stable state of $^{80}_{35}Br$ Ex:	N_n = variable, $A - 2Z$ = const.
Ex: $^1_1H, ^2_1H, ^3_1H$	Ex: $^3_1H, ^3_2He$	Ex: $^{13}_6C, ^{14}_7N$	ground state of $^{80}_{35}Br$	Ex: $^{23}_{11}Na, ^{27}_{13}Al$

⇒ Charge of nucleus – $q = +Ze$, here $Z = N_p$

size of nucleus – $V \propto A$ (volume, atomic mass) $\Rightarrow \dfrac{V_1}{V_2} = \dfrac{A_1}{A_2}$

surface area, $S = 4\pi R^2$

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}, \quad R = R_0 A^{1/3}$$

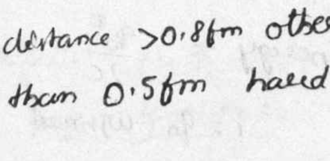
$$\frac{S_1}{S_2} = \left(\frac{R_1}{R_2}\right)^2 = \left(\frac{A_1}{A_2}\right)^{2/3}$$

here $R_0 = 1.2 \times 10^{-15}\ m = 1.2$ fermi $= 1.2\ fm$

⇒ volume of nucleus per nucleon $= \dfrac{4/3\,\pi R^3}{A} = 4/3\,\pi R_0^3$ = const.

density $= \dfrac{mass}{volume} = 2.3 \times 10^{17}\ kg/m^3$ = const

density of nucleus is independent on mass number, it is max at centre.



ρ at surface $= \dfrac{\rho_{centre}}{2}$

strongest forces ⇒ $F_g : F_e : F_n = 1 : 10^{36} : 10^{38}$

⇒ Nuclear force is attaractive when distance > 0.8 fm otherwise it is repulsive if less than 0.5 fm hard core repulsive force.

→ Nuclear force develop due to exchange of (π) phions. violation of L.C.M & E.

Mean life of $\pi^+ = 10^{-8}$ sec, of $\pi^- = 10^{-16}$ sec

rest mass of $\pi^+ = 273\,m_e$, of $\pi^- = 264\,m_e$

$n \rightarrow {}^0_1p + \pi^- \Rightarrow {}^1_0p + \pi^- \rightarrow n$, $p \rightarrow n + \pi^+ \Rightarrow n + \pi^+ \rightarrow p$

→ Mass defect : Mass defect (Δm) = total mass of nucleons − mass of nucleus

$= [Zm_p + (A-Z)m_n] - A \Rightarrow M - A$ (amu)

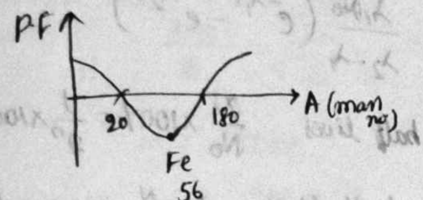
→ 1 amu $= 1.66 \times 10^{-27}$ kg, $B.E = \Delta m \times c^2 (J)$ (Δm in kg)

$= \Delta m \times 931.5$ MeV (Δm in amu)

(Binding energy) B.E per nucleon $= \frac{B.E}{A}$

→ if $\left(\frac{B.E}{A}\right)_I > \left(\frac{B.E}{A}\right)_{II}$ then nucleus I is more stable

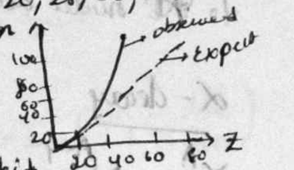
→ Least for deuterium = 1.1 MeV, high for iron = 8.7 MeV



stable of $20 < A < 180$.

→ B.E for nuclei of A b/w $80 < A < 170$ is const due to short ranged nuclear force.

→ Nuclear stability : The nuclei having 2, 8, 20, 28, 50, 82, 126 are always stable. $\left(\frac{n}{p} > 1\right)$.



⇒ Decay (or) disintegration:

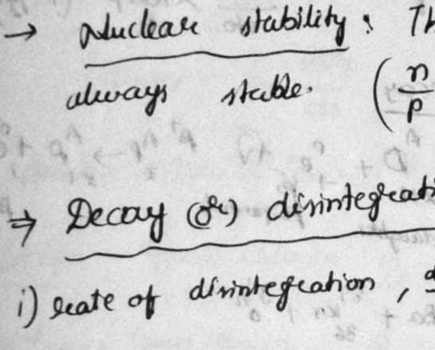
i) rate of disintegration, $\frac{dN}{dt} \propto N \Rightarrow \boxed{\frac{dN}{dt} = -\lambda N}$

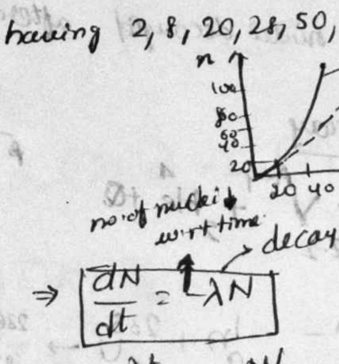
no. of nuclei ↓ w.r.t time; decay const.

ii) no. of nucleons undecayed $N = N_0 e^{-\lambda t} \Rightarrow N/N_0 = (1/2)^{t/T}$

iii) no. of nucleons decayed after certain time $= N_0 - N$
$= N_0(1 - e^{-\lambda t})$

iv) time required $t = \frac{1}{\lambda} \ln\left(\frac{N}{N_0}\right)$





⇒ Activity (R): rate of decay is activity

$R = -\lambda N_0 e^{-\lambda t}$

$R_0 = \lambda N_0$ (initial) $\Rightarrow \lambda = \lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_n$ → if simultaneous

1 BQ = 1 disintg/sec, 1 Rutherford $= 10^6$ disintg/sec

1 ci $= 3.69 \times 10^{10}$ disintg/sec

Half time : $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$

depends on nature of radioactivity

$$N_0 \xrightarrow{1} \frac{N_0}{2} \xrightarrow{2} \frac{N_0}{4} \xrightarrow{3} \frac{N_0}{8} \xrightarrow{n} \frac{N_0}{n}$$

$$N = \frac{N_0}{2^n} \Rightarrow \boxed{t = nT_{1/2}}$$

Mean life time (τ) : $\tau = 1/\lambda \Rightarrow \tau = 1.43(T_{1/2})$

successive integration $N_2 = \frac{\lambda_1 N_0}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$

% of nuclei present after 'n' half lives $\frac{N}{N_0} \times 100\% = \frac{1}{2^n} \times 100\%$

% ~~of~~ nuclei decayed after 'n' half lives $\frac{N_0 - N}{N_0} \times 100\% = \left(1 - 1/2^n\right) \times 100\%$

α-decay

$${}_{Z}X^{A} \rightarrow {}_{Z-2}Y^{A-4} + {}_{2}^{4}He + Q$$

β-decay

β^- ${}_{Z}^{A}P \rightarrow {}_{Z+1}^{A}D + {}_{-1}^{0}e + \bar{\nu}$ $\quad \beta^+$ ${}_{Z}^{A}P \rightarrow {}_{Z-1}^{A}P + {}_{1}^{0}e + \nu$

parent daughter β-particle β^+

Fission – ${}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{92}^{236}U \rightarrow {}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_{0}^{1}n$

$${}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{54}^{140}Xe + {}_{38}^{94}Sr + 2{}_{0}^{1}n$$

→ B.E released = B.E products − B.E reactants , B.E by columbic forces $b_C = \frac{-a_2 Z(Z-1)}{A^{1/3}}$

volume energy $b_v \propto A$