Nuclear Physics

Nucleus is made up of protons and ~~nuetrons~~ neutrons which are not fundamental particles. They are made up of quarks. protons have positive charge (+e) neutron have no charge

* Protons and neutrons are called nucleons

* due to like charge of protons they ~~are~~ have repulsive forces between them but still they are in nucleus so there must be an attractive force b/w them. This force is called strong nuclear force. This acts b/w all nucleons and this is short range force

Unit of mass

as masses of nucleons are very small so we introduce a unit that has very small value.
this is unified atomic mass unit (u)

It is mass of $\frac{1}{12}$th of Carbon-12 nucleus

Value

$$u = 1.66 \times 10^{-27}\ kg$$

Mass of any nucleus

$$^{b}_{a}X$$

a= number of protons

b= " " nucleons

Mass of nucleus X: b u kg

Example

$$^{12}_{6}C$$

$$\text{Mass of C-12} = 12 \times u$$
$$= 12 \times 1.66 \times 10^{-27}\ kg$$
$$= 1.99 \times 10^{-26}\ kg$$
$$= 12u$$

Mass of all nucleons of C-12 ?

$$6\,\underbrace{m_p}_{\text{mass of proton}} + 6\,\underbrace{m_n}_{\text{mass of neutron}}$$

$m_n = 1.00863\ u$

$m_p = 1.00728\ u$

~~$6 \times 1.672 \times 10^{-27} + 6 \times 1.67 \times 10^{-27}$~~

$= 6 \times 1.00863 + 6 \times 1.00728$

Sum of $= 12.095\ u$

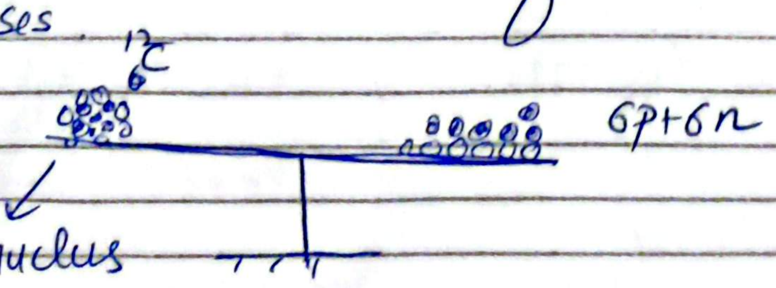
Mass of all ~~individual~~ nucleons = ~~2.00×10^{-26}~~ kg

Mass of nucleus is smaller than combined mass of all nucleons. This is known as mass defect.

Mass defect-

Difference of mass of nucleus and combined mass of all nucleons of that nucleus is called mass defect.

When nucleus is formed mass decreases.



mass defect of C-12

$\cancel{2.00 \times 10^{-26} - 1.99 \times 10^{-26}\ kg}$

$\cancel{0.01 \times 10^{-26}\ kg}$

~~in u~~ ~~divide by~~ $\cancel{1.66 \times 10^{-27}}$

$\cancel{0.06\ u}$

mass defect of C-12

$12.095\,u - 12\,u$

mass defect $= 0.095\,u$

$= 0.095 \times 1.66 \times 10^{-27}\ kg$

mass defect $= 1.577 \times 10^{-28}\ kg$

Binding energy

Energy required to move constituents of nucleus to infinity is called binding energy.

Einstein energy mass relationship.

Einstein showed that mass can be converted to energy and energy can be converted to mass.

The relationship is

$$\boxed{E = mc^2}$$

m : mass

c : speed of light $c = 3 \times 10^8 \, ms^{-1}$

mass of 0.1 kg have

$$E = 0.1 \times (3 \times 10^8)^2 = 9 \times 10^{15} \, J$$

Binding energy calculation

Binding energy $= \Delta m c^2$ Δm = mass defect

of C_{12} $= 1.577 \times 10^{-28} \times (3 \times 10^8)^2$

$= 1.42 \times 10^{-11} \, J$

Receipe to find binding energy of any nucleus

* Find combined mass of all nucleons
* Find mass of nuleus
* find mass defect (Δm)
* Use $E = mc^2$ to find binding energy
* to find binding energy per nucleon divide above answer by number of nucleons

electron volt (eV)

It is unit of energy

$1eV = 1.6 \times 10^{-19} J$

$1MeV = 1.6 \times 10^{-13} J$

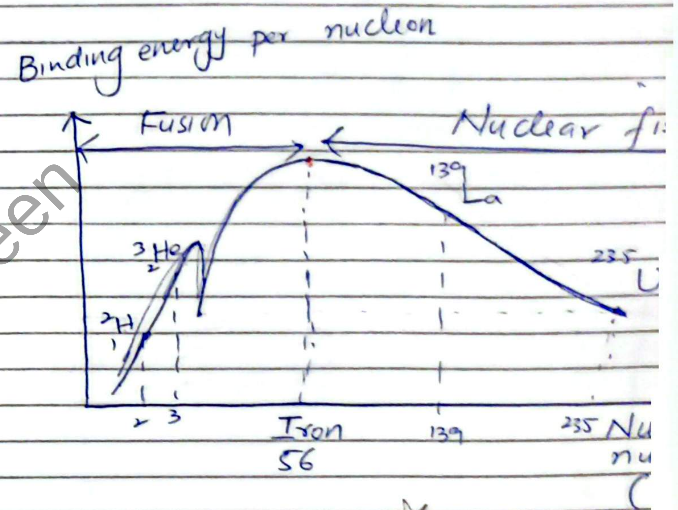
$V = \frac{W}{Q}$

$W = VQ$

$1eV = 1V \times 1.6 \times 10^{-19}$

$1eV = 1.6 \times 10^{-19} J$

Graph of binding energ[y] per nucleon with nucl[eon] number.



Iron is most stable

after this stability decreas[es]

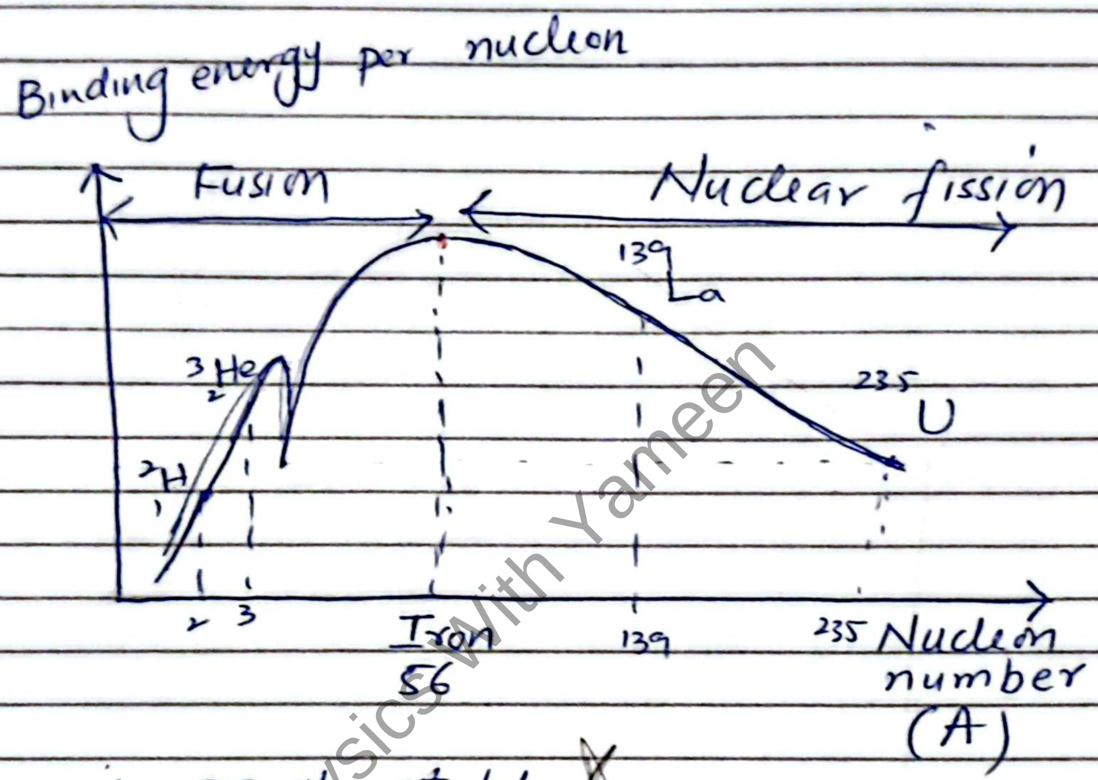
Nuclear Fusion

When two smaller nu[clei] form a haviour nucle[us]

$^2_1H + ^2_1H \longrightarrow ^3_2He +$

$^2_1H + ^3_1H \longrightarrow ^4_2He +$

Graph of binding energy per nucleon with nucleon number.



Iron is most stable ~~A~~

after this stability decrease

Nuclear Fusion

When two smaller nuclei form a haviour nucleus

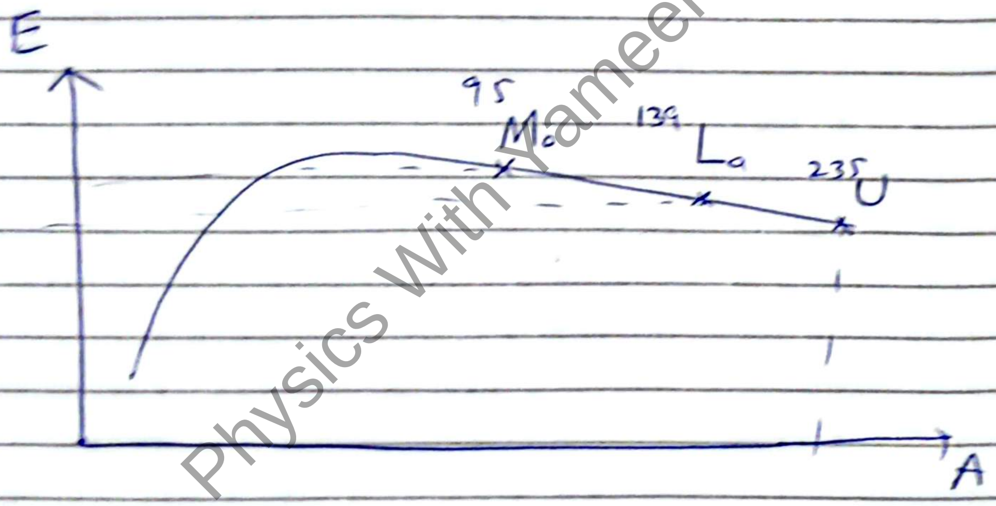
$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

Nuclear fission

spliting of havier nuclei into smaller nuclei is called Nuclear fission

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{95}_{42}Mo + ^{139}_{57}La + 2^{1}_{0}n + \dots$$



E: Binding energy per nucleon
A: Nucleon number.

How to find energy released in any reaction?

If mass of product is smaller than mass of reactants then energy is released

find mass difference $= \Delta m$

use $E = \Delta m c^2$

Radioactivity

~~Emission~~ of

Random and spontaneous emission of particles and electromagnetic radiation from an ustable nucleus

Spontaneous

Not affected by external factors like pressure, temperature

Random

We dont know ~~exa~~ exactly when a particular nucleus will decay.

Rate of decay is proportion to number of nuclei [...] at time.

$\frac{\Delta N}{\Delta t}$: Rate of decay

ΔN : Number of decayed nuc[...]

$$\frac{\Delta N}{\Delta t} \propto N$$

N : Number of undecayed nuclei at time.

N_0 = Number of undeca[...] nuclei at $t=0$

$$\frac{\Delta N}{\Delta t} = -\lambda N \qquad \frac{dy}{dx}$$

$$\frac{\Delta N}{N} = -\lambda \Delta t$$

$$\frac{dN}{N} = -\lambda dt$$

Rate of decay is proportional to number of nuclei present at time.

$\frac{\Delta N}{\Delta t}$: Rate of decay

ΔN: Number of decayed nuclei

$$\frac{\Delta N}{\Delta t} \propto N$$

N: Number of undecayed nuclei at time. t

N_0 = Number of undecayed nuclei at $t=0$

$$\frac{\Delta N}{\Delta t} = -\lambda N \qquad \frac{dy}{dx} = x$$

$$\frac{\Delta N}{N} = -\lambda \Delta t$$

$$\frac{dN}{N} = -\lambda dt$$

$$\int \frac{dN}{N} = -\int \lambda \, dt$$

$$\ln N = -\lambda t + c$$

at $t = 0$ $\quad N = N_0$

$$\ln N_0 = 0 + c$$

$$\ln N = -\lambda t + \ln N_0$$

$$\ln N - \ln N_0 = -\lambda t$$

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$\boxed{N = N_0 e^{-\lambda t}}$$

proof of this equation is not included in syllabus

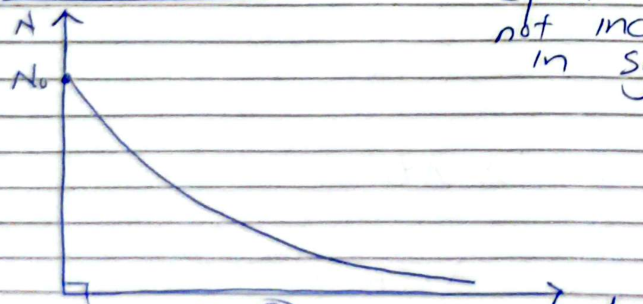


Fig ①

Decay constant

probability of decay of a nu... per unit time

$$\lambda = \frac{\frac{\Delta N}{N}}{\Delta t}$$

$\frac{\Delta N}{N}$ = probability of decay

unit of lambda (λ) $\quad s^{-1}$

Activity (A)

Rate of decay of nucle...

$A = \frac{\Delta N}{\Delta t}$; It is equal to grad... (N-t...

unit: Bacquerel (Bq)

$Bq = s^{-1}$

$$\lambda = \frac{\Delta N}{N \, \Delta t} = \frac{\Delta N}{\Delta t} \times \frac{1}{N}$$

$$\lambda = \frac{A}{N}$$

Decay constant (λ)

probability of decay of a nucleus per unit time.

$$\lambda = \frac{\frac{\Delta N}{N}}{\Delta t}$$

$\frac{\Delta N}{N}$ = probability of decay

unit of lambda (λ) s^{-1}

Activity (A)

Rate of decay of nucleus

$A = \frac{\Delta N}{\Delta t}$; It is equal to grad of (N-t graph) Fig 1

Unit: Bacqueral (Bq)

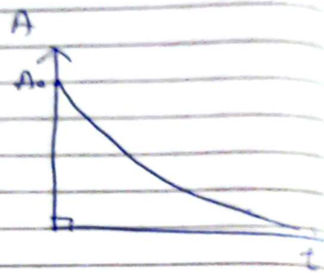
$Bq = s^{-1}$

$$\lambda = \frac{\Delta N}{N \Delta t} = \frac{\Delta N}{\Delta t} \times \frac{1}{N}$$

$$\lambda = \frac{A}{N}$$

$$\boxed{A = \lambda N}$$

$$A = A_0 e^{-\lambda t}$$



Half life $(t_{1/2})$

time during which number of nuclei, activity become half of its initial value

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

after one half life

$t_{1/2}$ $\quad N = \frac{N_0}{2}$

$$\frac{\cancel{N_0}}{2} = \cancel{N_0} e^{-\lambda t_{1/2}}$$

$$\frac{1}{2} = e^{-\lambda t_{1/2}}$$

$$\ln\left(\frac{1}{2}\right) = \ln\left(e^{-\lambda t_{1/2}}\right)$$

$$\underset{0}{\ln 1} - \ln 2 = -\lambda t_{1/2} \ \cancel{\ln e}$$

$$\cancel{-}\ln 2 = \cancel{-}\lambda t_{1/2}$$

$$\ln 2 = \lambda t_{1/2}$$

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

$$\lambda = \frac{0.693}{t_{1/2}}$$

Given on front page of paper.

$$\frac{1}{2} = e^{-\lambda t_{1/2}}$$

$$\ln\left(\frac{1}{2}\right) = \ln\left(e^{-\lambda t_{1/2}}\right)$$

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