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Where Minds Pollinate

Class 12
Physics

Chapter 22
Handwritten Notes

Q What is enrichment of Uranium?

conversion of non fissile $^{238}U \rightarrow {}^{235}U$ fissile is called enrichment of uranium.

enriched uranium is 3 to 5% enriched than before.

* Nuclear reactor is used to design a controlled nuclear reaction that can be beneficial for production of energy
  - moderator → neutron ko slow down krty
  - control rod → neutron ko absorb krty.
* pressurized water is in coolant having high B.p so that it can absorb large amount of heat.

decay law: (also known as activity)

→ $\frac{\Delta N}{\Delta t} \propto N$ (no. of atoms present in sample)

rate of decay

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

∴ −ve sign = amount of nuclei decrease during decay

λ = decay constant (s^{-1})

units;

> bq = 1 disintegration/second

> $1\,Ci = 3.7 \times 10^{80}$ Bq

> 1 Rutherford = $1\,R_H = 10^6$ Bq

nuclear fission:

- heavy nucleus are unstable so split into two smaller nuclei.

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^{*} \rightarrow {}^{141}_{56}Ba + Kr + 3\,{}^{1}_{0}n + Q$$

Q = 200 MeV

critical mass; mass of uranium required to sustain the fission chain reaction.

$m < m_c$ (stop)

$m = m_c$ (continous rxn)

$m > m_c$ (controlled chain rxn) (used in bombs)

- hydrogen bomb → nuclear fusion
- atomic bomb → nuclear fission

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α-decay:

$${}^{A}_{Z}X \longrightarrow {}^{A-4n}_{Z-2n}Y + {}^{4}_{2}He$$

for series of rxn

→ if 3 times α decay

$${}^{A}_{Z}X \longrightarrow {}^{A-4(3)}_{Z-2(3)}Y + {}^{4}_{2}He$$

β- decay:

- $${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}_{-1}\beta + \bar{\nu}$$ (antineutrino)

Q there is no e^- in nucleus then how rxn takes place?

$${}^{1}_{0}n \longrightarrow {}^{1}_{1}p + {}_{-1}e + \nu$$ (ismay ek proton emit howa balance krnay kay liyey ek $\bar{e}$ emit howa)

B-positive

- $${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}_{+1}\beta + \nu$$

$${}^{1}_{1}p \longrightarrow {}^{1}_{0}n + {}_{+1}e + \nu$$

half-life:

→ not one single nucleus studied but sample

- The time during which half of life decay in a given sample is called half-life. (half of the sample decay)

Remaining nuclei;

$$N_R = \frac{N_0}{2^n}$$ — N_0 - initial, n - half life

$$N_0 = N_0 - \frac{N_R}{2^n}$$ (atoms decaying)

$$N' = N_0 - N_R$$

$$\text{no. of half life} = \frac{T}{T_{1/2}}$$

for mass;

$$m = \frac{m_0}{2^n}$$

$$\frac{100g}{2^{(2)}} = \frac{100}{4} = 25$$

remaining mass = 26g.

formula:

$$B.E = [Zm_p + (A-Z)m_N] - m_{nucleus} \times c^2$$

packing fraction:

$$F = \frac{B.E}{A} \Rightarrow \frac{B.E}{(Z+N)}$$

→ binding energy per nucleon
→ tell us about the stability of nucleus
→ contribution of to B.E depends upon mass of nucleon

$\therefore \frac{B.E}{A} \uparrow$ (stable nucleus)

$\frac{B.E}{A} \downarrow$ (unstable nucleus)

radioactivity:

α^{+} β^{-} γ no charge

${}^{4}_{2}He$ (β^{-}, β^{+}) $\cdot E \uparrow$

e^{-} positron $\cdot \lambda \downarrow$

- mass of positron = e^{-} mass
- charge of positron = photon charge

- generally, β is negative due to e^{-} (fast moving e^{-})
- positron is called antiproton.
- γ are photon so no charge
- nuclear decay / nuclear transmotation (unstable → stable
  Parent → daughter)
- ionization;

$$\gamma < \beta < \alpha \ , \ I_\alpha > I_\beta > I_\gamma$$

penetration power;

$$P_\gamma > P_\beta > P_\alpha$$

mass defect: (also called mass deficit)

symbol; Δm

- mass of ncleons > mass of a seprate nucleus

- It is the difference of mass of nucleon and of mass of nucleus.

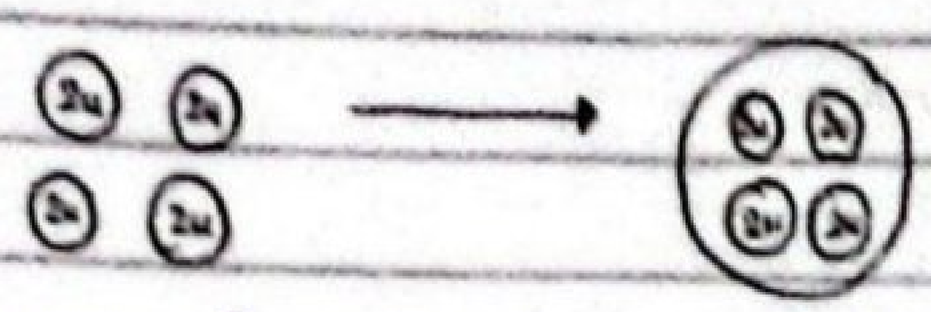
$$\Delta m = \text{mass of nucleons} - \text{mass of nucleus}$$

- formula;

$$\Delta m = [Zm_p + \underset{(A-N)}{N}m_N] - m_{nucleus}$$

$\therefore Zm_p$ = mass of proton, proton no.

$Nm_N = (A-Z)m_N$



mass of nucleons 8u

mass of nucleus 6u

(when seprated from one another)

↳ ~~bin~~ mass defect = 2u used in binding energy

binding energy ⇒ according to Eelnstein

$$B \cdot E = \Delta mc^2$$

$\therefore \uparrow B \cdot E \propto \Delta m \uparrow$

→ B·E Is the energy which binds the nucleus together inside the nucleus

B·E ↑ when Δm↑ so nucleus strongly held.

→ The energy required to seprate the nucleon from eachother

$$B \cdot E = (\Delta m) \times c^2$$

multiply and divide by 12 on b/s

$$\frac{\text{mass of 1 atom of C-12}}{12} = \frac{1}{6.022 \times 10^{26}} \text{ kg}$$

$$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$$

(Relation b/w amu & k)

masses of P, N and e:

$M_e = 0.000554\, u$ (largest particle)

$M_p = 1.00727\, u$

$M_n = 1.008665\, u$

Prove that $1u = 1.494 \times 10^{-10}$ J ?

by Einstein's mass-energy eq

$$E = mc^2$$

$$E = (1u)(3 \times 10^8)^2$$

$$E = (1.66 \times 10^{-27})(3 \times 10^8)^2$$

$$E = 1.49 \times 10^{-10} \text{ J}.$$

convert it into eV

$$E = \frac{1.49 \times 10^{-10} \text{ J}}{1.6 \times 10^{-19}}$$

$$E = 931 \text{ MeV}$$

CH:22 nuclear reaction

Symbol of nucleus = $^{A}_{Z}X$

$\therefore$ A = mass no. / nucleon no.
Z = atomic no. / proton no.

- Nucleons = protons + neutron (particles inside a nucleus)

A = nucleon no. = N+Z
Z = proton no. = Protons/electrons

no. of neutrons = A-Z

unit of mass:

- amu = u
- 1 amu = $\frac{\text{mass of one atom of C-12 atom}}{12}$

u = 1-12th of mass of one carbon-12 atom

- Prove that 1 amu = 1.66×10^{-27} kg ?

Sol:

mass of one mole of C-12 = 12g
mass of 6.022×10^{23} atoms of C-12 = 12g
multiply by k on b/s
$6.022 \times 10^{23} \times 10^{3}$ atoms of C-12 = 12kg
6.022×10^{26} of C-12 = 12kg
→ for mass of 1 atom of C-12
mass of 1 atom of C-12 = $\frac{12}{6.022 \times 10^{26}}$ kg.

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Data;

4) time = 40110 years
initial atoms = 10,000 atoms
half life = 5,730 years
find; $N_r = ?$

$$N_r = \frac{N_o}{(2)^n} \longrightarrow (i)$$

But $n = ?$

$$n = \frac{\text{total time}}{\text{half life}}$$

$$n = 7$$

$$N_r = \frac{10,000}{2^7}$$

$$N_r = 78.25 \text{ atoms} \longrightarrow \star$$

5) $\Delta m = ?$
B.E = ? MeV
mass of $^{107}_{47}Ag = 107.905949u$

Sol;

$$\Delta m = (\text{mass of nucleons}) - (\text{mass of nucleus})$$

$$\Delta m = (Zm_p + Nm_n) - (m)_{nucleus}$$

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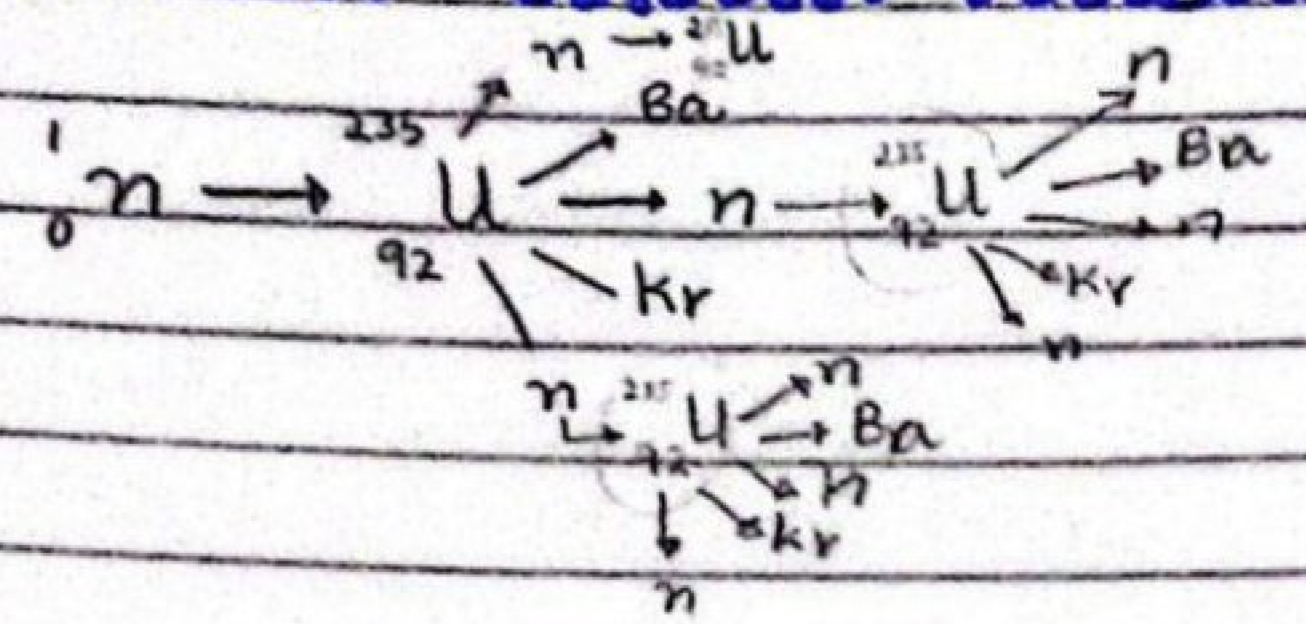
fission chain reaction:



critical mass:

It is the mininum amount of mass of Uranium (fissionable fuel) to sustain the fission chain reaction is called critical mass.

- if m_{fuel} = critical mass then chain reaction continue with uniform speed and used in nucleus reactor as a energy source.
- if m_{fuel} < critical mass Then chain reaction doesnot start.
- if m_{fuel} > critical mass then chain reaction continue with a rapid speed and used in atomic bombs

numerical problems:

energy released in one fission rxn:

$E = \Delta m \times 931.5$ MeV

$\therefore \Delta m = \left(\text{mass of reactants}\right) - \left(\text{mass of products}\right)$

· mass of reactants $=$ mass of ${}_0^1n$ + mass of ${}_{92}^{235}U$

$= 1.008665\,u + 235.121424\,u$

Mass of total $= 236.130085\,u$

$\Delta m = mass_r - mass_p$

$\Delta m = 236.130185 - 235.835194$

$\Delta m = 0.294891\,u$

$E = \Delta m \times 931.5$ MeV

$E = 0.294891 \times 931.5$

$E = 274$ MeV

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2)

$\lambda = 0.00012 s^{-1}$

$T_{1/2} = ?$

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

$$= 5775\ s$$

nuclear Fission:

The process in which a heavy nucleus converts into two lighter nuclei (nearly equal masses) along with two or three neutrons and large amount of energy is released in it.

invented in 1939.

$$\underset{\text{slow neutron}}{{}^{1}_{0}n} + \underset{\text{stable}}{{}^{235}_{92}U} \longrightarrow \underset{\text{unstable}}{{}^{236}_{92}U^*} \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + Q$$

A slow neutron hit ${}^{235}_{92}U$ and make it unstable ${}^{236}_{92}U^*$. This unstable nucleus converts into two lighter nuclei and $3\,{}^{1}_{0}n$ and large amount of energy. $\to$ K.E, heat

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^* \longrightarrow {}^{132}_{50}Sn + {}^{101}_{42}Mo + 3\,{}^{1}_{0}n + Q$$

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^* \rightarrow {}^{139}_{56}Ba + {}^{95}_{36}Kr + 2\,{}^{1}_{0}n + Q$$

energy released per reaction = 200 MeV

Q: why fusion rxn is difficult to achieve?

- very high temp
- lots of energy is used to overcome repulsion b/w nuclei.

numerical problems:

1)

Data;

$T_{1/2} = 10$ days

$N_o = 5000$ nuclei

$t = 30$ days (total time)

$N_R = ?$

$$\text{no. of half lifes} = n = \frac{\text{Total time}}{\text{half life}}$$

$$= \frac{10}{30} = 3$$

$$N_r = \frac{N_o}{(2)^n}$$

$$N_r = \frac{5000}{(2)^3}$$

$$= \frac{5000}{8}$$

$N_R = 625$ atom

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energy calculalism:

$$E = (\Delta m) \times 931.5 \text{ MeV} \quad \text{(if mass in amu)} \quad \leftarrow (i)$$

$$\Delta m = (\text{mass of reactant}) - (\text{mass of product})$$

mass of reactant;

mass of ^2_1H = 2.014102 u

" of ^3_1H = 3.016049 u

Total mass = 5.030151 u

mass of product;

mass of ^4_2He = 4.002603 u

" ^1_0n = 1.008665 u

Total mass = 5.011268 u

Δm = 5.030151u − 5.011268 u

= 0.01883 u

put in eq (i)

E = 0.01883 × 931.5 MeV

= 17.58

Energy released per nucleon;

$$\frac{\text{Energy released}}{\text{nucleon}} = \frac{17.58}{5}$$

= 3.51 MeV/nucleon.

• Nuclear fusion ... to achieve.

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$$E = (\Delta m) \times 931.5 \text{ MeV} \longrightarrow (i)$$

mass of reactant;

$$= 1.008665 + 235.12142$$
$$= 236.1301 u$$

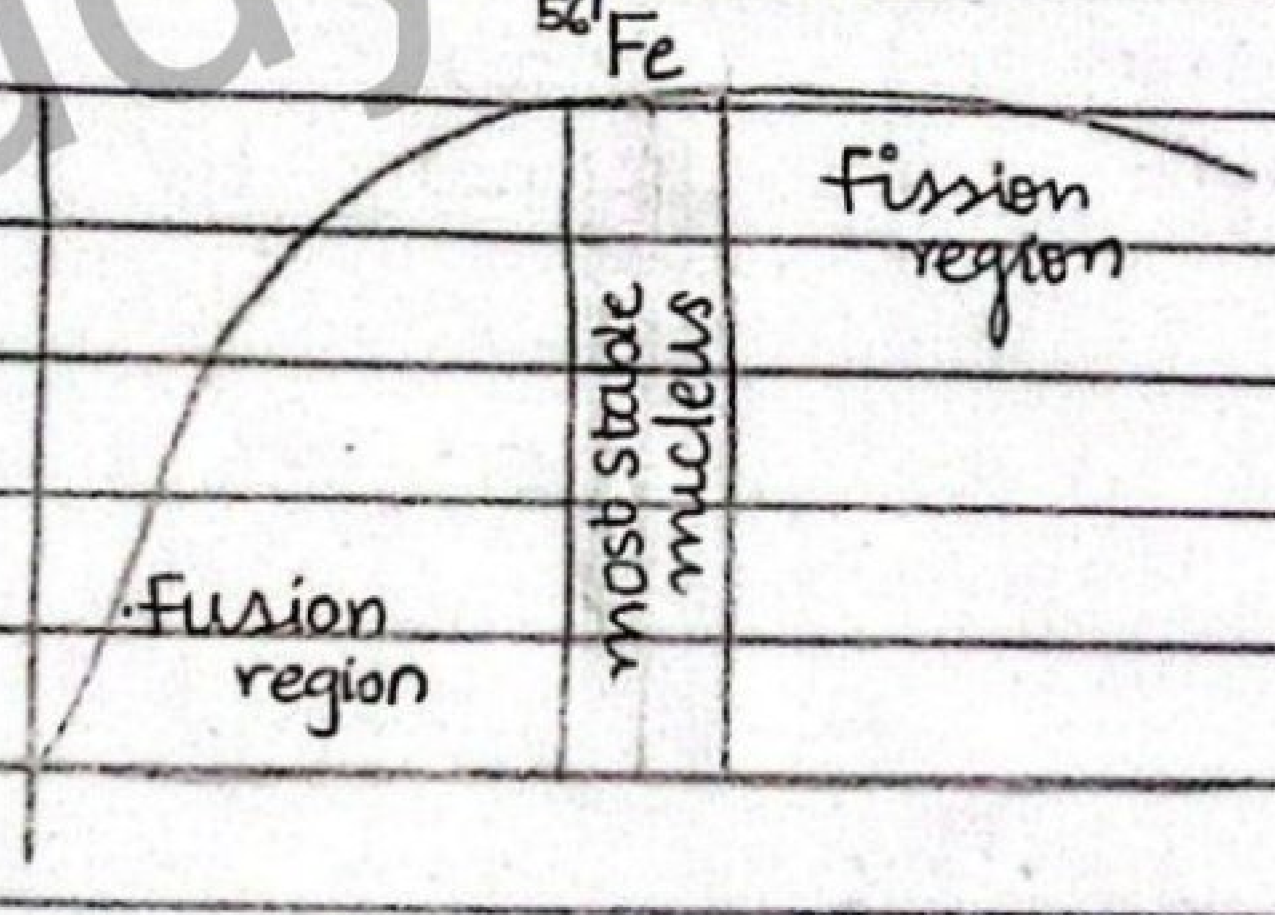
mass of product;

$$= 139.9055 + 93.9064 + 2(1.008665)$$
$$= 235.82923 u$$

$$\Delta m = 0.300855 u$$
$$E = 0.300855 \times 931.5 \text{ MeV}$$
$$E = 280.246 \text{ MeV}$$

nuclear Fusion:

"When two light nuclei come close to eachother to form a heavier nuclei and large amount of energy is released during the reaction is called nuclear fusion."



$$_{1}^{2}H + _{1}^{3}H \longrightarrow _{2}^{4}He + _{0}^{1}n + Q$$ (energy released)

> temp ~10 million Kelvin is needed (Hydrogen key) as they would repel so energy ↑ is given
> research → nuclear accelator (Voltage Giga eV)

during nuclear reaction;
i) Law of conservation of charge
ii) Law of conservation of mass no.
iii) Law of conservation of Energy.
iv) Law of conservation of Momentum.

law of conservation of charge:

Total charge on reactant = 2+7 = 9
total charge on product = 8+1 = 9

law of conservation of mass no.:

total mass of reactant = 4+14 = 18
total mass no. of product = 17+1 = 18

energy calculation in nuclear reaction:

$$E = (\Delta m) \times 931.5 \text{ MeV}$$

where,

$$\Delta m = \left(\begin{matrix}\text{mass of} \\ \text{Reactant}\end{matrix}\right) - \left(\begin{matrix}\text{mass of} \\ \text{product}\end{matrix}\right)$$

- if E = Negative → Energy is given to start the reaction.
- if E = Positive → Energy is released in the reaction.

assignment 22.7:

$$^{1}_{0}n + ^{235}_{92}U \xrightarrow{Q=?} ^{140}_{54}Xe + ^{94}_{38}Sr + 2\,^{1}_{0}n + Q$$

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assignment 22.6:

$T_{1/2} = 9.70$ hours
$= 9.70 \times 3600s$

$T_{1/2} =$

$\lambda = ?$

$\lambda T_{1/2} = 0.693$

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

$\lambda = \underline{0.693}$

nuclear reactions: (nucleus interaction)

"nuclear reactions are the processes in which atomic nuclei interact and as a result change into others nucleus and absorb or release the same amount of energy."

$a + X \longrightarrow Y + b$

"when a nucleus 'X' is bombard by a light nucleus (particle) (photon) Then as a product a heavy particle 'Y' and a light particle 'b' (photon, neutron, α-particle) is produced.

first reaction was performed by rutherford

$${}^{4}_{2}He + {}^{14}_{7}N \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H + Q$$

here Q is the amount of energy absorbed/released.

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

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

$$e^{\lambda T_{1/2}} = 2$$

Taking 'ln' on both side

$$\ln e^{\lambda T_{1/2}} = \ln(2)$$

$$\lambda T_{1/2} = \ln(2)$$

$$\boxed{\therefore \lambda T_{1/2} = 0.693}$$

$$\lambda = \frac{0.693}{T_{1/2}}, \quad T_{1/2} = \frac{0.693}{\lambda}$$

find the no. of remaining atoms:

decay →
remaining atom ←

after 1^{st} half life: $1T_{1/2} \Rightarrow N_R = \frac{1}{2} N_0$ (50%)

" 2^{nd} half life: $2T_{1/2} \Rightarrow N_R = \frac{1}{2}\left(\frac{1}{2} N_0\right) = \frac{1}{4} N_0$ or $\left(\frac{1}{2}\right)^2 N_0$ (25%)

" 3^{rd} half life: $3T_{1/2} \Rightarrow N_R = \frac{1}{2}\left(\frac{1}{4} N_0\right) = \frac{1}{8} N_0$ or $\left(\frac{1}{2}\right)^3 N_0$ (12.5%)

general:

after n-half life

$$N_R = \frac{N_0}{2^n}$$

$$\ln N_0 = -\lambda(0) + \text{const}$$

$$\ln N_0 = \text{constant}$$

put in eq no.(1)

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

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

Taking exponential on b/s

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

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

relation b/w decay constant and half life:

$$\lambda T_{1/2} = 0.693 \longrightarrow \lambda = \frac{0.693}{T_{1/2}}$$

After 1st half life;

$$t = 1 T_{1/2} \quad , N = N_0/2$$

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

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exponential nature of nuclear decay:

- radioactive decay is exponential in a nature.
- rate of radioactive substance is proportional to no. of undecayed nuclei present at any given time.

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

for very small change, we can write,

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

$$\frac{1}{N} dN = -\lambda dt$$

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

Taking integration on bothside

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

$$\ln N = -\lambda \int dt$$

$$\ln N = -\lambda t + \text{constant} \longrightarrow (i)$$

at starting $t=0$, $N=N_0$

Activity:

disintegration per second

$$A = \frac{-\Delta N}{\Delta t}$$ (no. of atoms decayed per time)

activity and decay constant;

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

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

$$A = -N\lambda$$

$\therefore \lambda$ = decay constant

$\therefore N$ = no. of atoms

$A \propto N \rightarrow$ more amount = more activity

unit A:

SI unit; Becquerell (Bq)

" One Bq = $\frac{\text{one disintegration}}{1s}$ "

very small unit;

" 1 Curie = $\frac{3.7 \times 10^{8} \text{ disintegration}}{1s}$ "

decay rate:

The no. of atoms decaying persecond is called decay rate.

$$\frac{\Delta N}{\Delta t} \propto -N$$ (no. of atoms present = more decay rate)

"negative sign show that with respect to time, number of atom decreases"

$$\frac{\Delta N}{\Delta t} = -(\text{constant})\, N$$

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

$\therefore \lambda$ constant of proportionality decay constant.

decay constant:

$$\lambda = \left(\frac{\Delta N}{\Delta t}\right)\left(\frac{1}{N}\right)$$

$$\lambda = \left(\frac{\Delta N}{N \cdot \Delta t}\right)$$

↳ fraction of atom decay

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

It is the fraction of decay atoms per unit time or number of atoms decay per unit time.

- in unit time, more number of decay = more decay constant and viceversa

$$\lambda \propto \frac{1}{T_{1/2}}$$

unit; s^{-1}

decay constant depends only on the nature of decay.

Q How much time a sample would take to decay?
Infinite time would be required.

Half life:

It is the time in which half of the radio-active atom in a sample will decay is called half life.

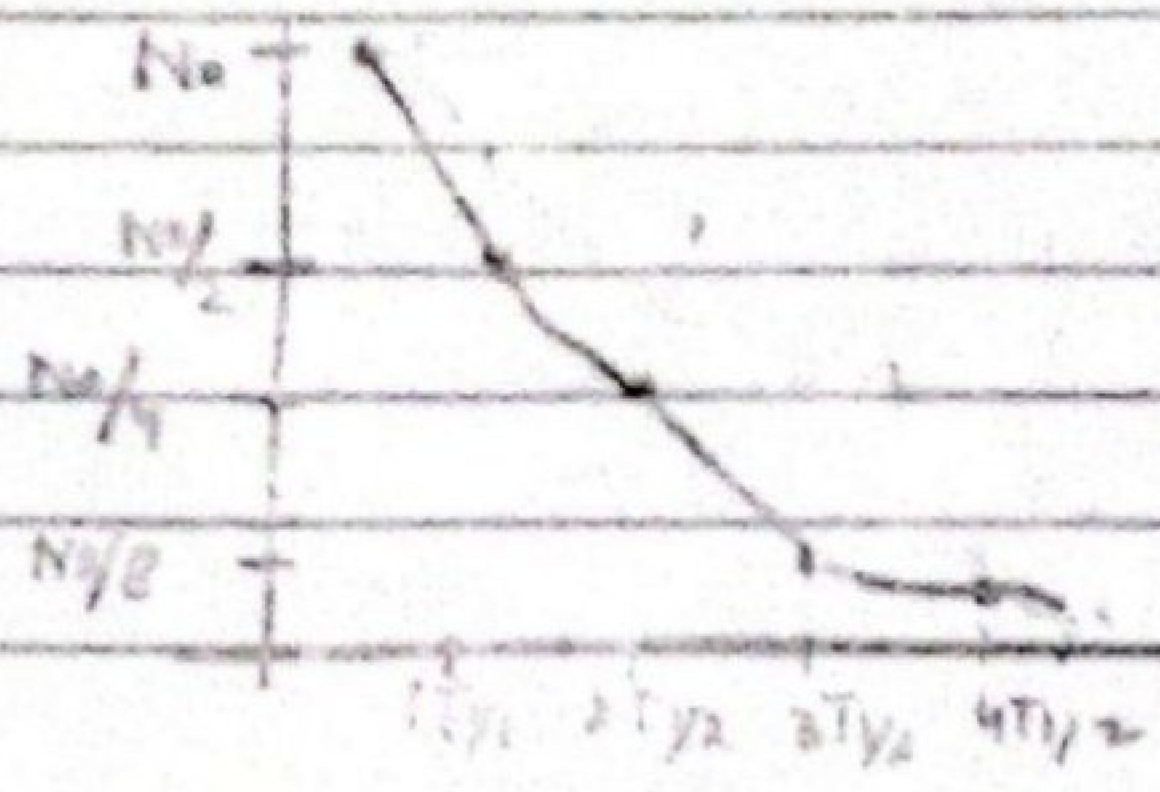
half life is radioactive phenomena
(random and spontaneous)

dependence:

"half life depend upon only nature of radioactive element"

Initial no. of atoms = 1000 atom
after 1st half life = 500 atoms = $1T_{1/2}$
after 2nd " = 250 atoms = $2T_{1/2}$
after 3rd half life = ~~250~~ 125 atoms = $3T_{1/2}$

it takes ∞ time for all the atoms of a radioactive material to decay.



natural:

It happens because the nucleus is seeking a more stable state.

count rate:

"The number of decays detected per unit time is called as count rate"

most common is the Geiger-Muller counter

count rate varies over time even if the conditions remain constant.

spontaneity:

We cannot predict the exact time of decaying for any single nuclei, this property is known as "spontaneity"

This is the reason that the count rate over longer periods becomes more stable and predictable in spite of showing fluctuations over short interval decays.

independent:

- external factors

applications;

energy productions, medicine, materials science

spontaneous, independent, random

emission of high energy photon from the nucleus

general:

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

*excited parent nucleus

"during γ-emission no effect on atomic mass as well as atomic number."

example;

$$_{27}^{60}C^{*} \longrightarrow {}_{27}^{60}Co + \gamma$$

during gamma-radiation only energy level of the nucleus change.

spontaneous and random nature of nuclear decay:

random:

Radioactive decays is a random process, it is impossible to predict exactly when a particular unstable nucleus will decay.

it may decay just on the moment you started observing it or it may not decay even for years.

emission of high energy photon from the nucleus

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

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positive β-decay:

emission of positron from the nucleus

- Proton decay ⟶ neutron + positron + neutrino

$${}^{1}_{1}H \longrightarrow {}^{1}_{0}n + {}^{0}_{+1}e + V$$

stay in the nucleus

emit from nucleus

"during +ve β-decay no effect on atomic mass, atomic no. decreases by 01"

A = remain same

Z = Z−1

- proton > neutron sey tu +ve β-decay ki possibility

general:

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e + V$$

example;

$${}^{10}_{6}C \longrightarrow {}^{10}_{5}B + {}^{0}_{+1}e + V$$

gamma decay:

when an atomic nucleus transitions from a higher energy state to a lower energy state.

the emission of gamma radiation can result in the change in energy of nucleus

beta decay:

Nature of Beta is either e^- or positron

types of beta decay;

i) negative B-decay

ii) positive B-decay

negative B-decay:

"emission of e^- from the nucleus."

neutron decay ⟶ proton + electron + anti~~nucleous~~ neutrino

$${}^{1}_{0}n \longrightarrow {}^{1}_{1}H + {}^{0}_{-1}e + \nu^-$$

proton stay in the nucleus

emit from the nucleus

- during -ve β-decay no effect on the mass no.
- atomic no. = increase by one.

A = remain same

Z = increase (+1)

general; $${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \nu^{-1}$$

example, $${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e + \nu^-$$

alpha decay:

emission of ^4_2He nucleus Helium nucleus consist of two proton and two neutron.

"during alpha decay atomic mass decreases by 4 & atomic no. decreases by 2."

general:

$$^{A}_{Z}X \longrightarrow ^{A-4}_{Z-2}Y + ^4_2He + Q$$

parent nucleus — daughter nucleus

example:

$$^{235}_{92}U \longrightarrow ^{231}_{90}Th + ^4_2He + Q$$

Q) What is effect on mass no. and Neutron ratio?
N : Z

neutron - proton ratio:

In parent nucleus,

$$\frac{N}{Z} = \frac{143}{92} = 1.53$$

In daughter nucleus,

$$\frac{N}{Z} = \frac{141}{90} = 1.56$$

(N:Z) increases

mass, charge, & conserved

properties	α-particle	β-particle	gamma
nature	helium nucleus	e^-/postiron	photon (emitted from nucleus)
symbol	${}^{4}_{2}He$	${}^{0}_{-1}e$ / ${}^{0}_{+1}e$	γ
charge	+2e	e/e^- (same as e^-) ~~0.00054u~~	neutral
mass	4.002603 u	0.00054u	rest mass (0)
v	0.05-0.1 c	0.5c - 0.9c	speed of light
ionization	highest	medium	lowest
penetration	lowest (bcs of high charge ionize and heavy ja)	medium	highest
stopped by	a sheet of paper	a sheet of aluminium	lead sheet
sources	Radon 222	Stratium 90	cobalt 60

- Penetration and Ionization are inversely related
- Energy = Penetration + utilized in Ionization

$$\frac{E_B}{A} \propto (\text{stability of nucleus})$$

Radioactivity:

- natural phenomena
  $A > 82$
  → naturally unstable and emit invisible radiation
- It is the phenomena in which the element whos atomic mass is more than 82 naturally emit invisible radiation.

unstable nucleus $\xrightarrow[\text{radiation}]{\text{emit}}$ to gain stability

cause of radiation:

disintegration of nucleus
independent on any chemical or physical reaction. (temp, pressure etc, independent)
radioactivity is random process.
We cannot predict which atom is going to be decayed.

parent molecule/nucleus → jissey radiation nikaley.

"binding energy per nucleon gives the stability of nucleous" (not the B·E)

i) $B \cdot E = 2000$ MeV

$A = 240$

$\frac{B \cdot E}{A} = 8.3$ MeV/nucleon

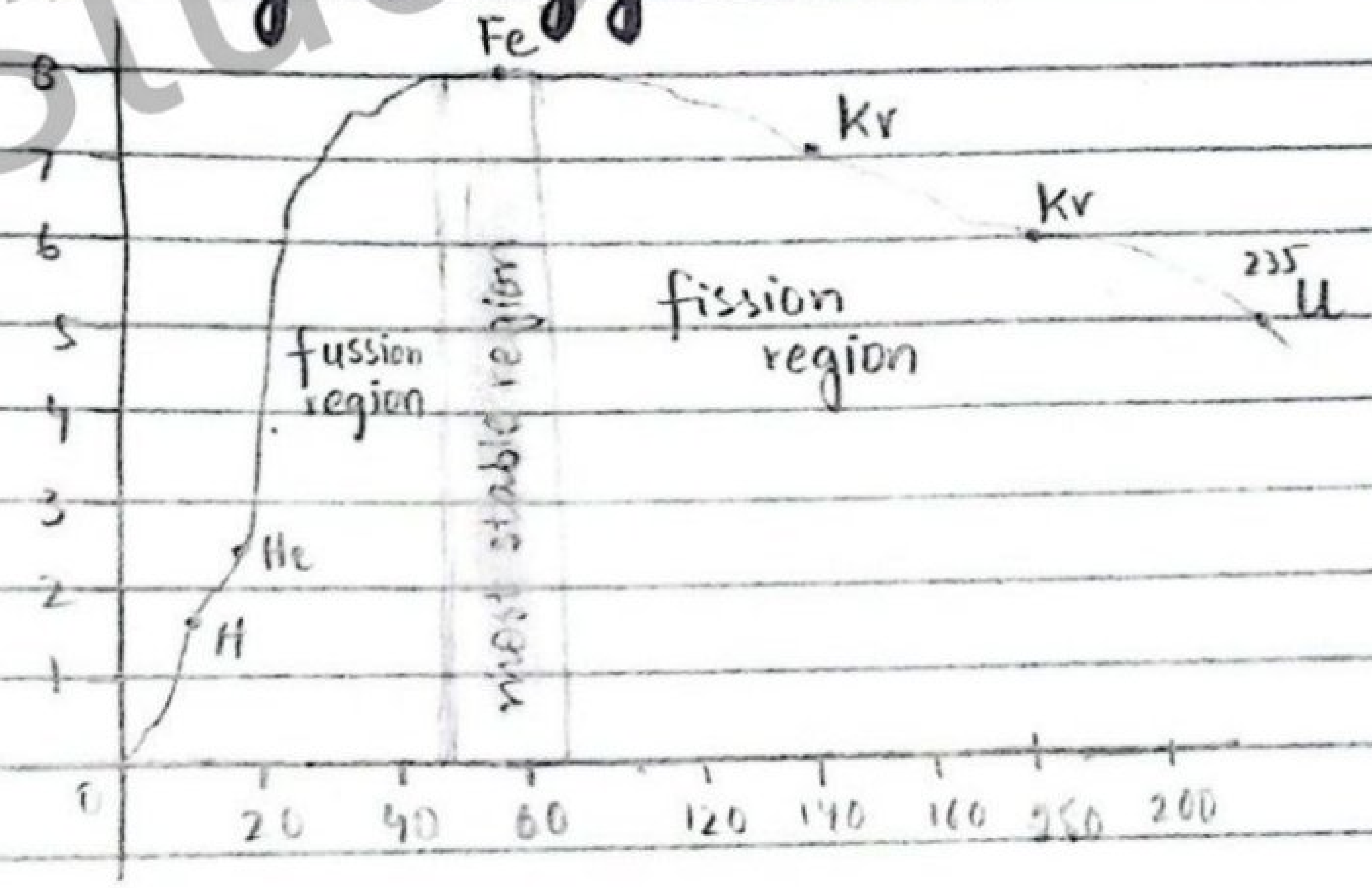
ii) $B \cdot E = 200$ MeV

$A = 22$

$\frac{B \cdot E}{A} = 9.09$ MeV/nucleon

packing fraction ; $\frac{B \cdot E}{A}$

binding energy curve:



Fe - most stable nucleus!

$$E_B = \left((Zm_p + Nm_n)\right) - m_{nucleus} \times 931.5 \text{ MeV}$$

$$= \left[(2\times1.007276)+(2\times 1.008665)\right]-(4.002603)\times 931.5 \text{ MeV}$$

$$E_B = (4.031800 - 4.002603) \times 931.5 \text{ MeV}$$

$$E_B = 27.3 \text{ MeV}$$

binding energy per nucleon:

"Total B.E divided by total no. of nucleons give B.E per nucleon"

$$\frac{E_B}{A} = \left(\frac{\Delta m \times 931.5}{A}\right) \text{MeV/nucleon}$$

nucleon no. — A

e.g;

E_B for $^4_2He = 27.3$ MeV

$A = 4$

$$\frac{E_B}{A} = \frac{27.3}{4}$$

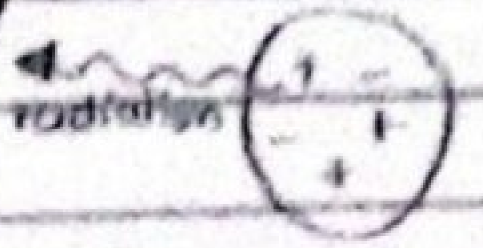
$$= 6.82 \text{ MeV/nucleon.}$$

B.E depends upon Δm;

$\uparrow$ atomic mass $\propto$ B.E $\uparrow$

MeV — B.E value > I.E (keV)
always in eV.

break the nucleus into its constituent particles (proton + neutron) is called bindinding energy.



"when we bind the e^- some of mass is loss for the energy needed to bind them"

mathematically:

using einstein mass-energy equation.

$$E_B = \Delta m \cdot c^2$$

Δm = mass defect (in kg)

E_B = in joule.

If Δm is in amu,

$$E = \Delta m \times 931.5 \text{ MeV}$$

now, E_B is in <u>MeV</u>

$$E_B = \Delta m \times c^2$$

$$E_B = \left[\left(Zm_p + Nm_n\right) - m_{nucleus}\right] \times c^2 \dashrightarrow \star$$

$$E_B = \left[\left(Zm_p + Nm_n\right) - m_{nucleus}\right] \times 931.5 \text{ MeV} \dashrightarrow \star$$

helium;

for helium nucleus (^4_2He)

mass of ^4_2He - nucleus = 4.0026034

energy making = energy breaking

$$\Delta m = \left(\text{mass of proton} + \text{mass of neutron}\right) - \text{mass of nucleus}$$

$$\Delta m = (Zm_p + Nm_n) - m_{nucleus}$$

Z = no. of proton
m_p = mass of proton
N = no. of neutron
m_n = mass of neutron

Q Find the mass defect in Carbon nucleus?

mass of $^{12}_{6}C = 12.0000\ u$
$m_p = 1.007276\ u$
$m_n = 1.008665\ u$
$\Delta m = [Zm_p + Nm_n] - m_{nucleus}$

$\Delta m = [6(1.007276) + 6(1.008665)] - 12.0000$
$\Delta m = 12.095646 - 12.0000$
$= 0.095646\ u$

binding energy:

"It is the energy which bind the nucleons in the nucleus called binding energy."

OR

It is the minimum energy required to

relation b/w 'u' and 'joule':

using Einstein mass energy eq;

$$E = mc^2$$

put $m = 1u = 1.6606 \times 10^{-27}\,kg$

and $c = 3 \times 10^{8}\,m/s$

$$E = (1.6606 \times 10^{-27})(3 \times 10^{8})^2$$

$$E = 1.49 \times 10^{-10}\,J$$

$$1u = 1.49 \times 10^{-10}\,J \longrightarrow *$$

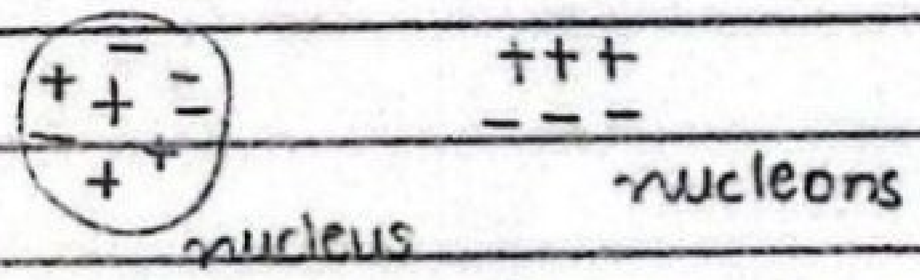
convert it into eV;

$$1u = \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-19}}\,eV$$

$$1u = 931.5 \times 10^{6}\,eV$$

$$1u = 931.5\,MeV \longrightarrow *$$

mass defect: (Δm)



mass of combined nucleus is always less than mass of individual ~~molecules~~ (nucleons) which formed the nucleus.

This difference in mass of nucleons to the mass of nucleus is called mass defect.

$$\Delta m = (\text{mass of nucleons}) - (\text{mass of combined nucleus})$$

example;

$^{12}_{6}C$ → $Z=6$, $A=12$, $N=6$

$^{13}_{6}C$ → $Z=6$, $A=13$, $N=7$

$^{14}_{6}C$ → $Z=6$, $A=14$, $N=8$

nuclear masses:

- nuclear masses are not measured in kg (due to extremely small mass) so for measuring the mass at nucleus / atomic level a new unit is introduced called atomic mass unit. (amu)

def of 1 amu; (1u)

$$1u = \frac{1}{12}^{th} \text{ part of } ^{12}C = \text{atom.}$$

relation b/w 'u' and 'kg'

$$1u = 1.6606 \times 10^{-27} kg \longrightarrow \star$$

nuclear physics

nuclear physics:

"It is a branch of physics in which we study about the structure, properties related to atomic nucleus is called nuclear physics."

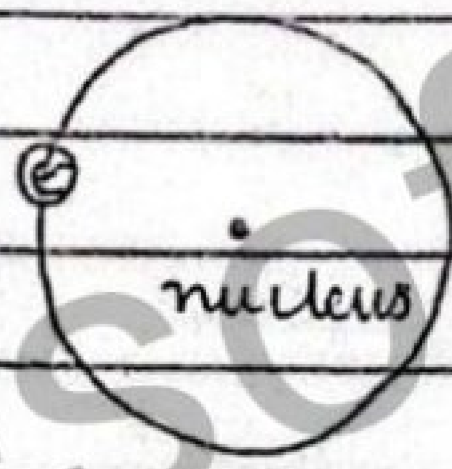
What is atomic nucleus?

central part of atom.

charge = positive
(positive charge depends upon no. of proton)

$q = Ze$

Z = no. of proton
e = charge on proton
$= 1.6 \times 10^{-19}\ C$



- atom → neutral
- e^- → negative
- nucleus → positive (proton)

mass; 99.99% mass of the atom lie inside the nucleus.

Size; radius $= 10^{-14}\ m$

while size of the atom is $10^{-10}\ m$.

nucleus is 10,000 times smaller than atom (10^4 times)

- nucleus is heavy particle

Density of the nucleus is very high.

"density of nucleus is constant."

"with the increase in mass and size density remain constant"

$^{A-2}_{Z-2}X$

atomic no. : (Z)(A)

Z = No. of proton in the nucleus.

· unique no. (two diff nuclei do not have same atomic no.)

atomic mass : (A)(Z)

A = (Z + N) → nucleon

neutron no. (N)

number of neutron present in the nucleus is called neutron no.

N = A-Z

e.g;

U_{92} → Z = 92, → A = 233, → N = 143

isotopes :

atom of same elements which has same atomic number different atomic mass

no. of proton = same

no. of neutron = different

· same chemical properties.

· different physical properties.

CH#22 Nuclear-Physics.

⇒ proton + neutron = nucleons.

⇒ symbol : $^{A}_{Z}X$ — A = mass no / nucleon no, Z = atomic no / charge no

where Z = no of protons.

⇒ $A = Z + N$ = proton + neutron

⇒ $N = A - Z$ = No of neutron.

$^{4=A}_{2=Z}He$ $P = 2$, $A = 4$, $N = 4 - 2 \Rightarrow \boxed{N = 2}$

Unit of mass amu (u).

Short Q. $1u = \frac{\text{mass of one carbon atom (C-12)}}{12}$

Prove that $1u = 1.66 \times 10^{-27}$ kg.

Proof:- mass of 1 mole of C-12 = 12g

Mass of 6.02×10^{26} atom of C-12 = 12kg.

Mass of one atom of carbon 12 = $\frac{12}{6.02 \times 10^{26}}$ kg

$\frac{\text{mass of one atom of C-12}}{12} = \frac{12}{12(6.02 \times 10^{26})}$ kg

$1u = \frac{1}{6.02 \times 10^{26}}$ kg.

$\boxed{1u = 1.66 \times 10^{-27} \text{ kg}}$

$m_e = 0.000549u$

$m_p = 1.007276u$

$m_n = 1.008665u$.

Short Question.

$1u = 931 MeV$.

$E = mc^2$

$E = (1u)(3\times10^8)^2$

$E = (1.66\times10^{-27})(3\times10^8)^2$

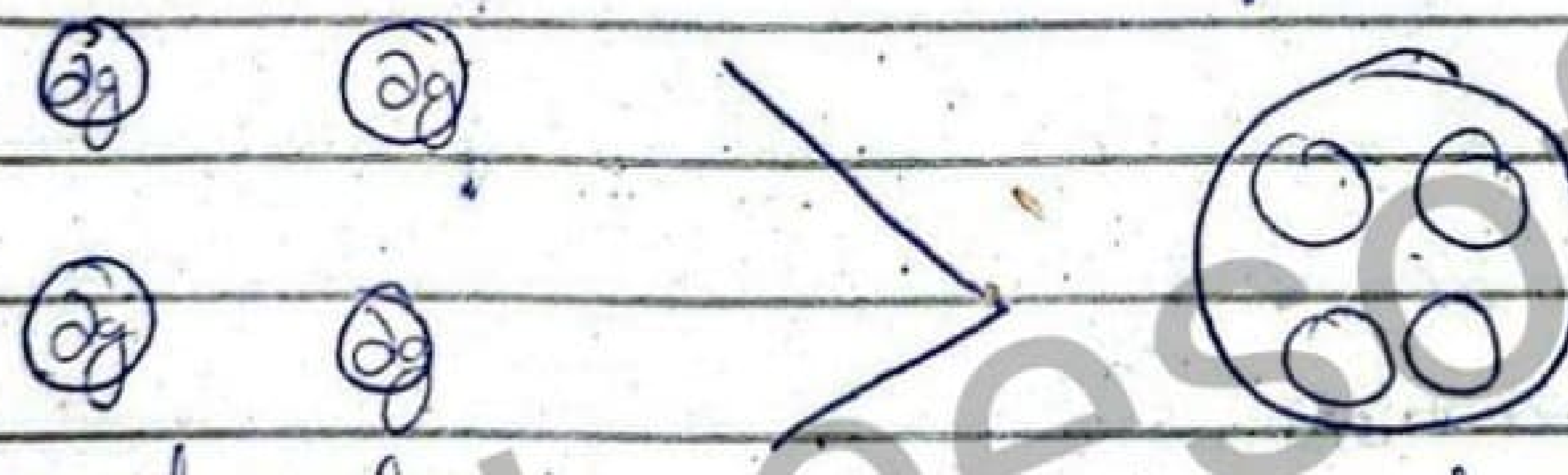
$\boxed{E = 1.494\times10^{-10} J}$ $\Rightarrow E = \frac{1.494\times10^{-10}}{1.6\times10^{-19}}$

$\boxed{E = 931 MeV}$

• Mass-Defect / Mass-Deficit :-

Symbol :- Δm

Mass of seperate nucleons :- $>$ mass of combine nucleus



Mass of nucleons $= 8g$ — Mass of nucleus $= 6g$

$\Delta m =$ Mass of nucleons $-$ mass of nucleus

$\Delta m = [Zm_p + (A-Z)m_{neutron}] - m_{Nucleus}$.

mass defect goes in binding energy.

Binding energy

$B.E = \Delta mc^2$

$B.E = [Zm_p + (A-Z)m_n]c^2 - m_N c^2$

Defination:- Energy required to bind the nucleons together.

OR

energy required to seperate nucleons from each other

Head

CH# 22

Binding-energy per nucleon / packing-Fraction :

$\therefore f = \frac{B.E}{A}$

- $\frac{B.E}{A} \uparrow$ stable nuclei

- $\frac{B.E}{A} \downarrow$ unstable nuclei.

$B.E = 24J$

$A = 6$

$\frac{B.E}{A} = \frac{24}{6} = \boxed{8}$

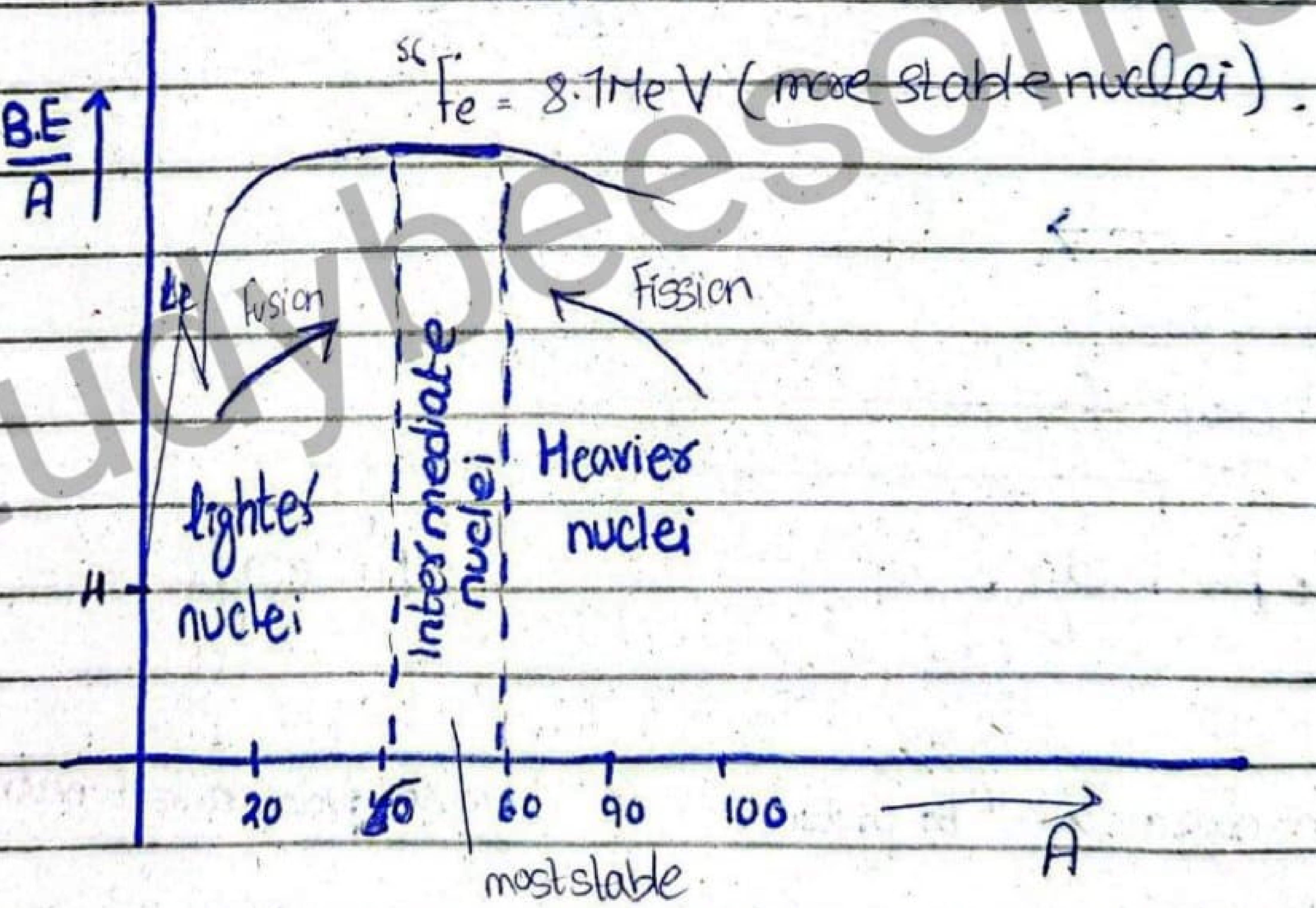
Radio Active Decay:- Spontaneous emission of radiation from unstable nuclei these elements are called radioactive element and radiation are called radioelement radiation
e.g α, β and γ radiation.

- **α-particle:-** α are helium nuclei. (^4_2He)
  i.e $Z=2$, $A=4$, $N=2$
- +vely charged
- Deflect toward negative plate in electric field.
- α particle deflect less in magnetic field.
- High-ionization power.
- Low penetration power.
- **β-particle:-** β particle are fast moving elec[illegible] and positron. $\underset{-\beta}{\bar{e}} / \underset{+\beta}{e^+}$
- -vely charge
- Deflect toward positive plate in E-field

- More deflect in Magnetic field
- low ionization
- ~~low~~ High penetration –

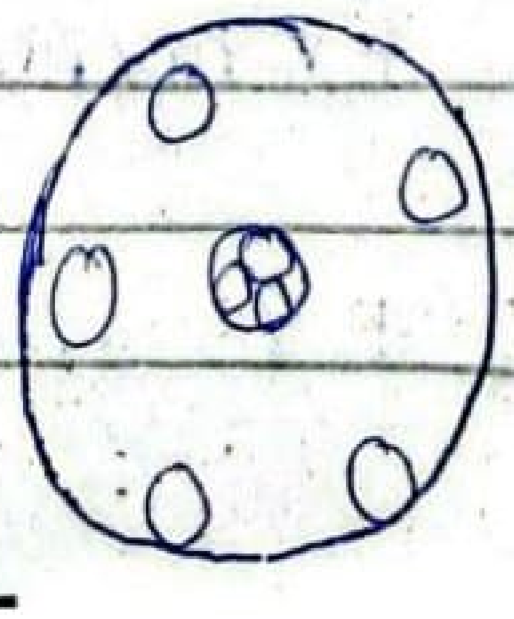
γ- particle :- • High energy photon
- Neutral
- No effect of electric field
- no effect of Magnetic field.
- Very low ionization power
- Very high penetration.

Binding energy Curve :- ⇒ Graph b/w $\frac{B.E}{A}$ and A



Q) Why lighter nuclei are unstable?

Ans)



→ surface effect

→ more nucleon lies on surface of nucleus as compare to

Half life:- Time during which half atom of sample decay.

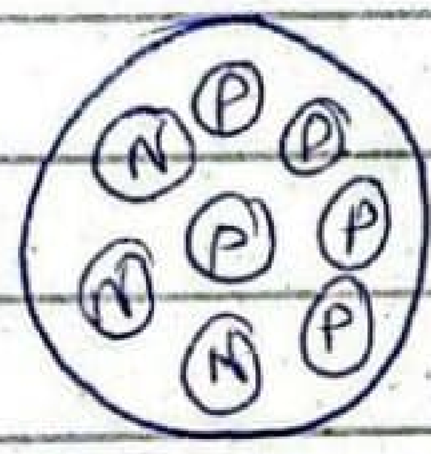
to nucleons at centre.

→ $f = \frac{B.E}{A}$ less.

→ Lighter nuclei unstable.

Q) Why heavier nuclei are unstable?

Ans)



→ no of proton > no of neutron

→ High repulsion force

→ $\frac{B.E}{A}$ less

→ Unstable nuclei

α-Decay:- $_{Z}^{A}X \longrightarrow {}_{Z-2}^{A-4}Y + {}_{2}^{4}He$ (α)

parent nuclei — daughter nuclei

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

β-Decay:-

• β^- - Decay (electron)

$_{Z}X^{A} \longrightarrow {}_{Z+1}Y^{A} + {}_{-1}\beta + \bar{\nu}$ (antineutrino)

• when neutron convert to proton

$_{0}^{1}n \longrightarrow {}_{1}P^{1} + {}_{-1}\beta + \bar{\nu}$

• β^+-Decay (positron)

$_{Z}X^{A} \longrightarrow {}_{Z-1}Y^{A} + {}_{+1}\beta + \nu$

• when proton convert neutron

$_{1}P^{1} \longrightarrow {}_{0}n^{1} + {}_{+1}\beta + \nu$

γ-Decay:- $_{Z}^{A}X^{*} \longrightarrow {}_{Z}^{A}X$ + γ-ray photon

unstable/excited state.

A: same

Z: same

e.g $_{27}^{60}Co^{*} \longrightarrow {}_{27}^{60}Co$ + γ-ray photon

Spontaneous nuclear Decay: ⇒ Natural process

⇒ without external cause

⇒ No external factor (T, P, E.F, M.F) can speed up or slow down

⇒ Due to nuclear unstability.

⇒ Automatically process.

Random nuclear Decay:- ⇒ unpredictable process

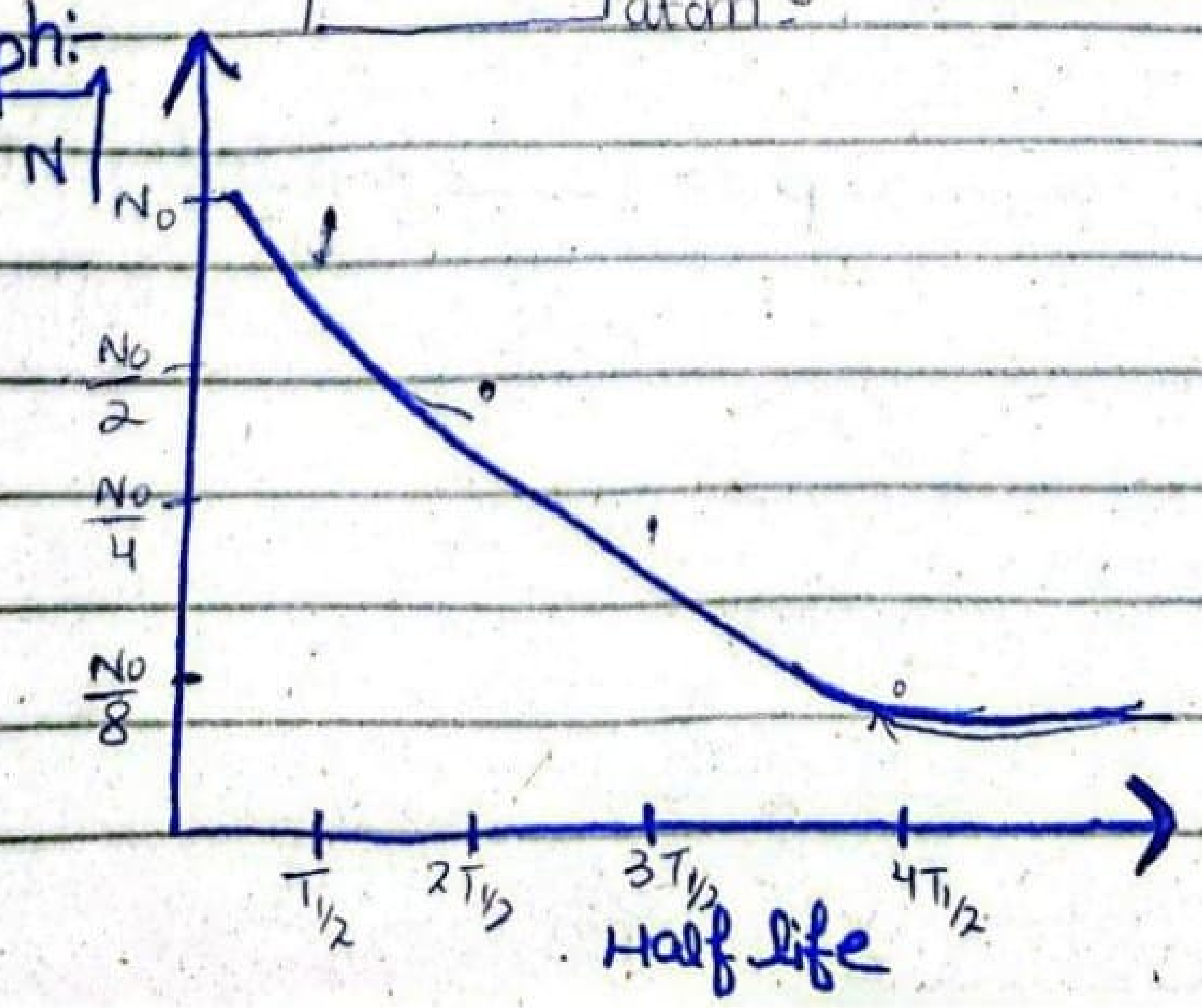
⇒ No particular nucleus decay next

⇒ Exact time of decay is unpredictable

⇒ Only particle probability can be predicted.

Half life	Remaining atoms (N)	Decay atoms (N')
initial atoms (N_0) $n=0$	N_0	0
$n=1$	$\frac{N_0}{2}$	$N_0 - \frac{N_0}{2} = \frac{N_0}{2}$
$n=2$	$\frac{N_0}{2^2}$	$N_0 - \frac{N_0}{4} = \frac{3}{4}N_0$
$n=3$	$\frac{N_0}{2^3}$	$N_0 - \frac{N_0}{8} = \frac{7}{8}N_0$
$n=n$	Initial atom $\boxed{\frac{N_0}{2^n} = N}$ remaining atom	$\boxed{N_0 - \frac{N_0}{2^n} = N'}$

Graph:-



$\lambda = 620nm$

Acad Ch#22

Decay Law:- "Rate of Decay is directly proportional to No of atoms present in sample".

Formula:-

$$\frac{\Delta N}{\Delta t} \propto -N \quad \because -ve = \text{decreases}$$

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

· **Decay Constant (λ)**

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

$$\lambda = \frac{\frac{\Delta N \text{ — no of decay}}{N \text{ Initial}}}{\Delta t}$$

"Fraction of Decay per time"

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

Unit of $\lambda = s^{-1}$

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

or

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

Activity (A) $\Rightarrow A = \frac{\Delta N}{\Delta t}$

$\Rightarrow$ Activity is rate of decay

$\Rightarrow$ Activity is disintegration per second

Unit of A :- ① Baqural (Bq)

$1 Bq = 1$ disintegration per second

② Curi (Ci)

$1\,Ci = 3.7 \times 10^{10}\,Bq$

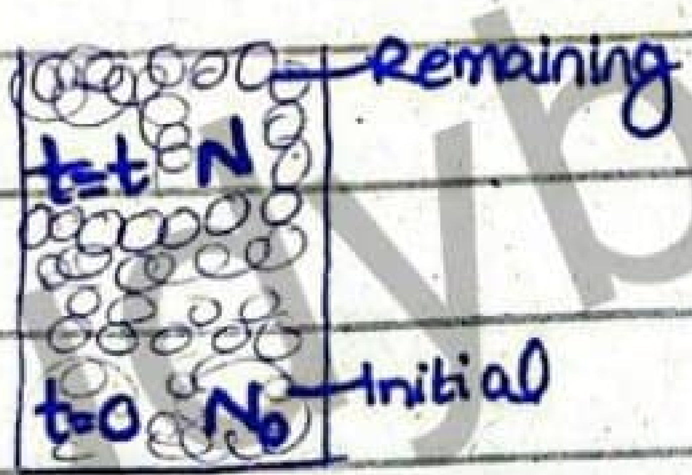
③ Rutherford (Rd)

$1\,Rd = 10^{6}\,Bq$

Q) **Exponential nature of nuclear decay** :- or

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

Proof:-



By Decay Law :- $\frac{\Delta N}{\Delta t} = -\lambda N$

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

Integrate both sides

$$\int_{N_0}^{N} \frac{\Delta N}{N} = -\lambda \int_{t=0}^{t} \Delta t$$

$$\ln N \Big|_{N_0}^{N} = -\lambda\, t \Big|_{0}^{t}$$

$$\ln N - \ln N_0 = -\lambda(t-0)$$

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

Taking anti-log (e) on bothsides-

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

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

(1) Relation between λ (decay const) and $T_{1/2}$ (Half Life).

or

Prove that $\boxed{\lambda T_{1/2} = 0.693}$

Proof:- Since

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

put $t = T_{1/2} \Rightarrow N = \frac{N_0}{2}$

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

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

$$2 = e^{+\lambda T_{1/2}}$$

apply ln on both sides

$$\ln(2) = -\lambda T_{1/2}$$

$\boxed{0.693 = \lambda T_{1/2}}$ proved on nxt page

Acad

Enrichment of Uranium: → Converting of non-fissil uranium (U-238) into fissil uranium (U-235).

→ **Methods** ① Gaseous - Diffusion

② Gas - centrifugation

③ laser - enrichment.

① · **Gaseous - Diffusion:-** → Convert uranium into gas called uranium hexafloride (UF_6).

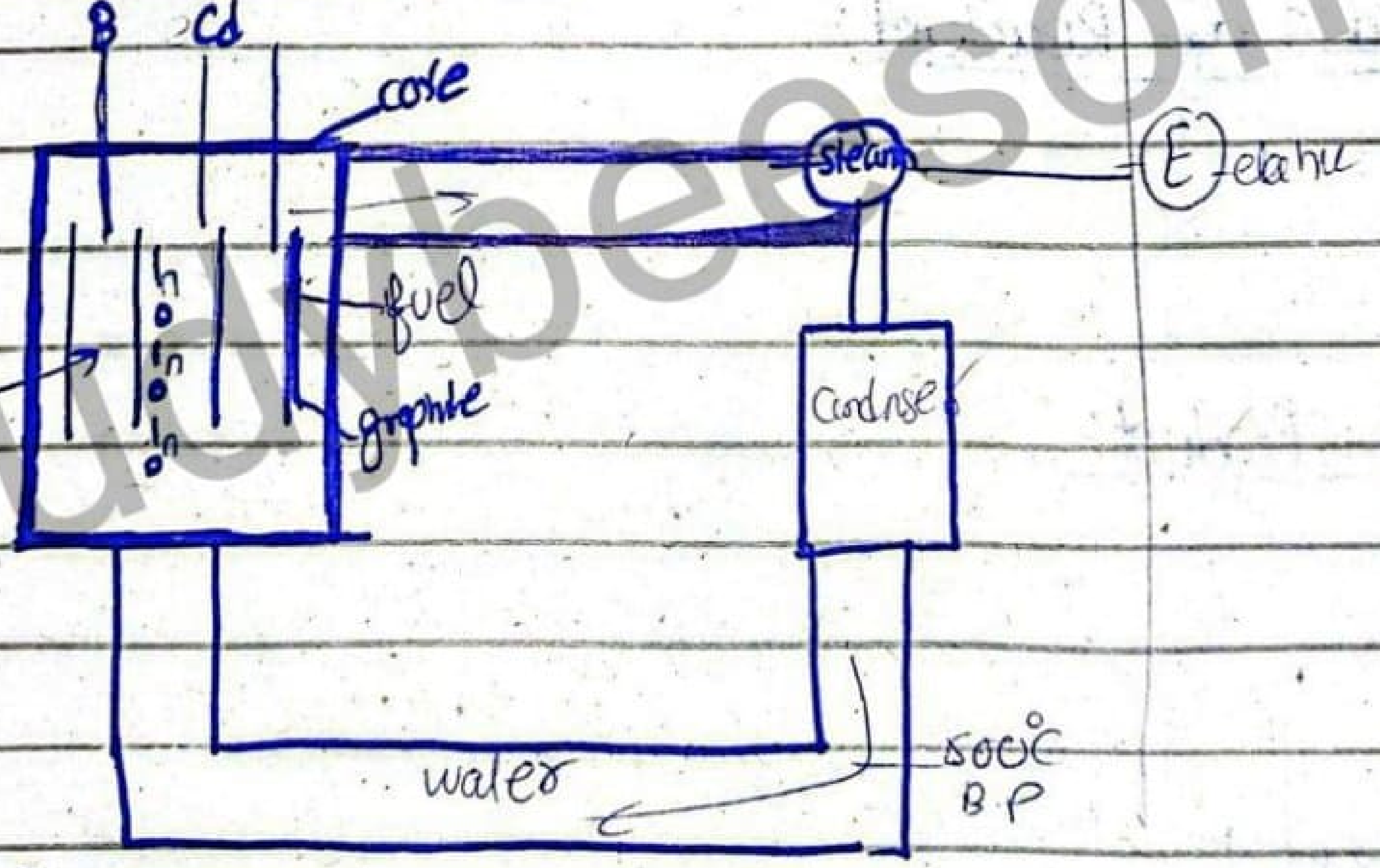
→ This gas contain both lighter (U-235) and heavier (U-238)

→ Pass UF_6 through porous barrier.

→ U-235 faster than U-238.

→ This way 3% — 5% increases of U-235.

Nuclear Reactor:-



Defination: It is a device used to start and sustain control fission chain reaction.

Principal: control fission chain reaction.

Construction: ① Core.

② **Fuel** → U-235 or P-239
→ rods of diameter 1m
→ Fissil uranium

③ **Moderator** → slowdown the fast neutron
→ absorb energy of neutron

To be continue

Acad.

Nuclear Reaction:- $a + X \longrightarrow Y + b + Q$.

$^{4}_{2}He + ^{10}_{7}N \longrightarrow ^{17}_{8}O + ^{1}_{1}H + Q$.

Q = energy released/absorbed
Q = +ve (exothermic)
Q = -ve (endothermic)

Nuclear Fusion:- ⇒ smaller nuclei combine to form heavy nucleus.

⇒ Condition: ⇒ High temp
⇒ High energy
⇒ Material confinment.

Example:

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

⇒ **Energy - calculation.**

Mass of Reactant:-

Mass of $^{2}_{1}H$ = 2.014102 u
Mass of $^{3}_{1}H$ = 3.016049 u
Total mass = 5.03015 u

Mass of Product:-

mass of $^{4}_{2}He$ = 4.002603 u.
mass of $^{1}_{0}n$ = 1.008665 u.
Total mass = 5.011267 u.

Mass Defect:-

Δm = mass of reactant — mass of product
Δm = 5.03015 − 5.011268
Δm = 0.018882 u

Energy:- $Q = (\Delta m)(931\ MeV)$

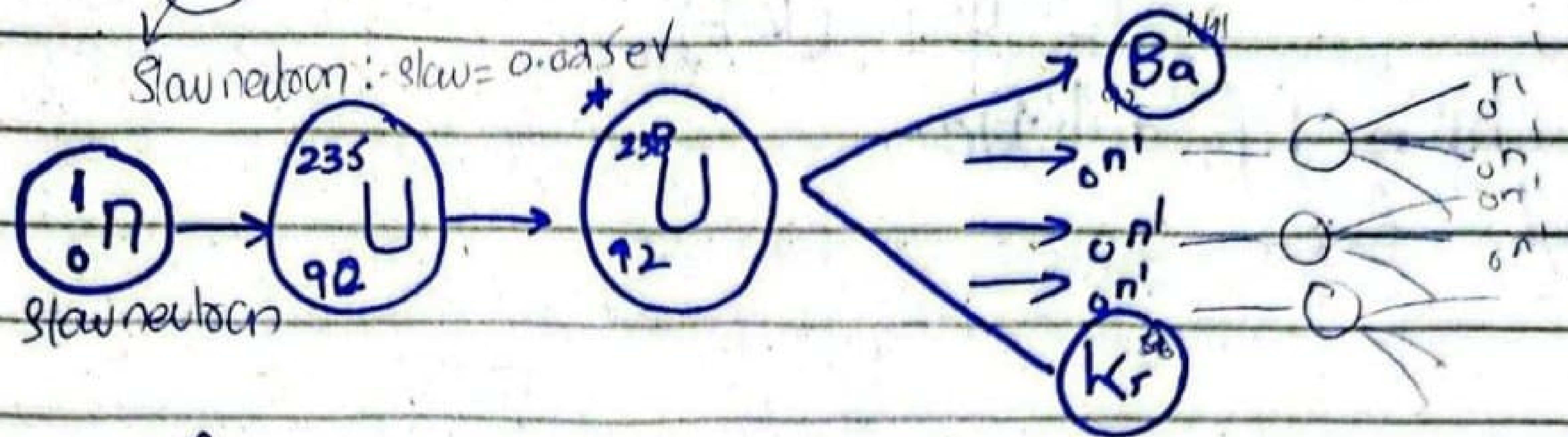
$\boxed{Q = 17.43\ MeV}$

Nuclear Fission :- ⇒ split heavy into small nuclei

⇒ $^{1}_{0}n + ^{235}_{92}U \longrightarrow U^{238}_{92} \longrightarrow ^{141}_{56}Ba + ^{92}_{38}Kr + 3\,^{1}_{0}n + Q$

Slow neutron :- slow = 0.025 eV

⇒



⇒ $Q = 200\,MeV$

$\boxed{\frac{Q}{A} = 0.9\,MeV}$

. Fission chain reaction :- neutron produce in one fission continue further fission

Critical mass :- ⇒ Mass of uranium for chain reaction

⇒ $m < m_c$ (no rxn)

⇒ $m = m_c$ (chain rxn)

⇒ $m > m_c$ (uncontrol chain rxn).

Mass of fission material required for control fission chain reaction

$^{238}_{92}U \longrightarrow 99.3\% \Rightarrow$ non fission uranium.

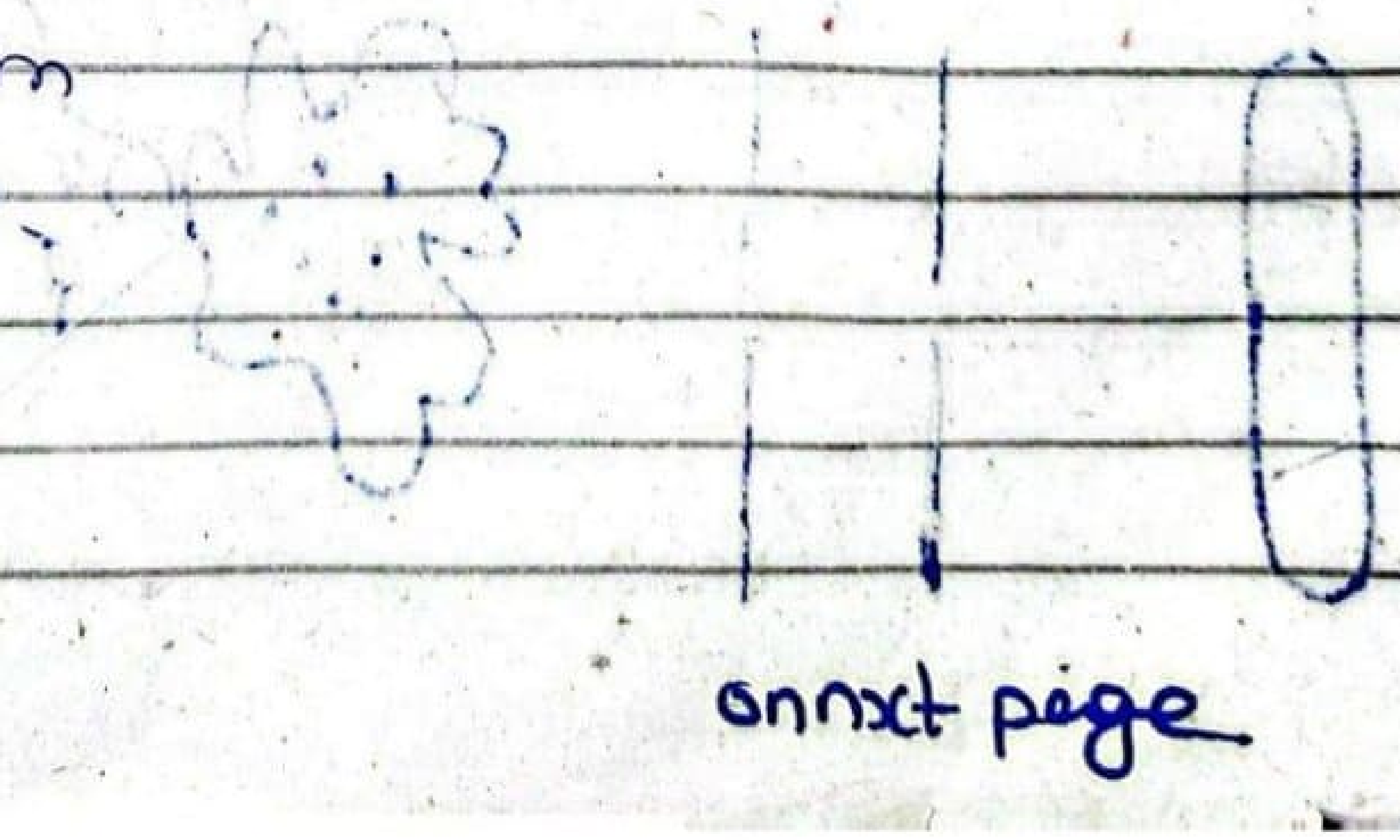
$^{235}_{92}U \longrightarrow 0.7\% \rightarrow$ Fissil uranium.

Continue previous

(4) **Control rod :-** → absorb $^{1}_{0}n$

→ Boron or cadmium

→ Control reaction



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CH#22 SHORT Questions:-

(1)

Benefit

1. Large amant energy
2. Low cost
3. No pollution
4. Continous scurce of energy (not effect by T, P, Humidity)

Draw backs:-

1. Radioactive radiation
2. waste product disposal.
3. Initial cost high.

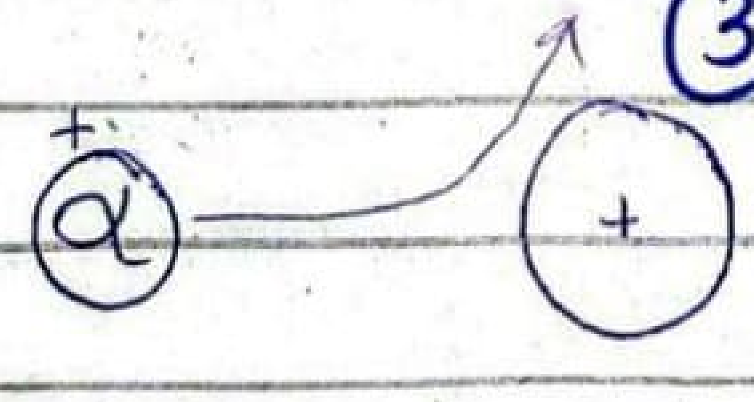
(2)

(a) $^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}_{-1}\beta + \bar{\nu}$ (same)

(b) $^{A}_{Z}X + e^- \longrightarrow {}^{A}_{Z-1}Y + {}_{+1}\beta + \nu$ (same)

(c) $^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ (α)

(3)



→ Both have +ve charge

→ Strong repulsion

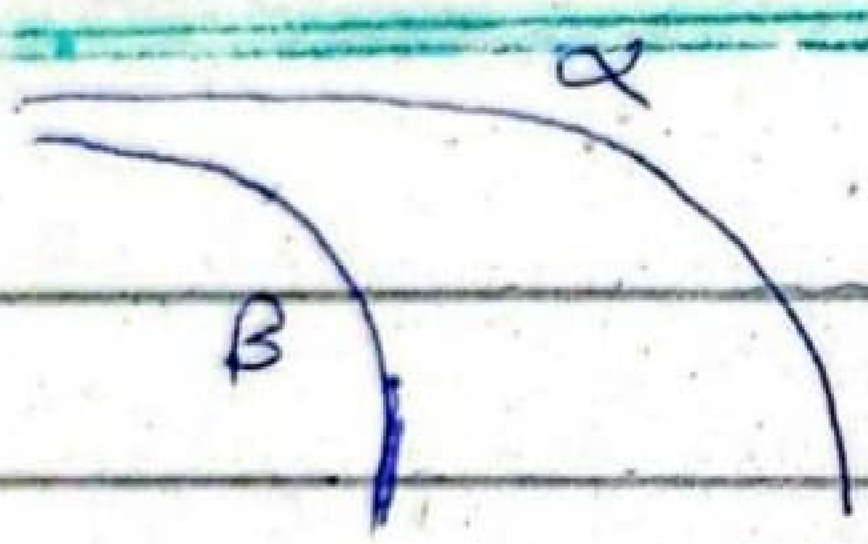
→ direct interaction not possible.

(4)

→ $m_\alpha >> m_\beta$

→ $v_\alpha >> v_\beta$

→ α particle less ↓ as compared β

→ 

4

5 Q8

Answer) → $_{92}U^{238}$ = 99.3% (not fissil)

→ $_{92}U^{235}$ = 0.7% (fissil)

→ Enrichment of $_{92}U^{235}$ by gas-diffusion (3% – 5%)

6

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

Thorium

7

4) ⇒ neutron produce i's fission. continue further fiss

⇒ fission chain reaction

⇒ Control fission chain reaction : (m_c)

⇒ Uncontroll fission chain reachr

$> m_c$

Numerical CH# 22

(1)

Data:- $T_{1/2} = 10 day$

$N_0 = 5000$

$N = ?$

$T = 30 day$

formula: $n = \frac{T}{T_{1/2}} = \frac{30}{10} = \boxed{3}$

$\therefore N = \frac{N_0}{2^n}$

$N = \frac{5000}{2^3} = \frac{5000}{8} = \boxed{625}$

(4)

$N = ?$ $T = 40110 year$ $N_0 = 10,000$

$T_{1/2} = 5730 years$

So $n = \frac{T}{T_{1/2}} = \frac{40110}{5730} = \boxed{7}$

$\therefore N = \frac{N_0}{2^n} = \frac{100,00}{2^7} \Rightarrow \boxed{78}$

(2)

$\lambda = 0.00012 s^{-1}$

$T_{1/2} = ?$

$\lambda T_{1/2} = 0.693$

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

$T_{1/2} = \frac{0.693}{0.00012}$

$\boxed{T_{1/2} = 5775 sec}$

CamScanner

③

$$ {}_0^1n + U_{92}^{235} \longrightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3{}_0n^1 + Q $$

Mass defect (Δm)

Δm = mass of reactant − mass of product

$$\Delta m = (1.008664 + 235.01461) - (140.98721 + 92.01431 + 3\times 1.008664)$$

Δm =

Q = ________ × 931 MeV

= ________ A

⑥

⑤

Silver = Ag_{47}^{108} $Z = 47$; $A = 108$, $N = 61$

$$\Delta m = [Zm_p + (A-Z)m_n] - m_{Ag}$$

$$\Delta m = [47(1.007275) + 61(1.008664)] - 107.9872$$

Δm = ________ u

Q = ________ × 931 MeV = ________ Joules

Ch# 22 Nuclear Physics

In nucleur physics we study nucleus systematic

→ **Atomic Nucleus:** 1911 ⟶ Rutherford

mass of atom is 99.9% mass of nucleus

. **Size of Atom** is measured in terms of Bohr radius that is approximately equal to 10^{-10} m

. **Size of Nucleus** is 10^{-15} m or **fm** or fermi

· **Radius of nucleus** $R = R_0 A^{1/3}$

$R_0 = 1.2$ fm

$R_0 = 1.2$ fermi

e.g C_6^{12}

$$\boxed{R = 1.2 \times 10^{-15} (12)^{1/3}}$$

. **Nucleus is composed of two composite particle:**

i.e Proton and neutron

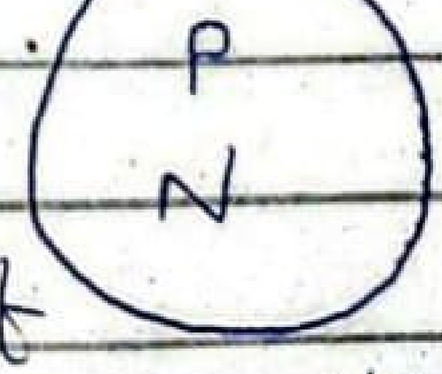
Proton: is a composite particle made up of three quarks having 1 unit positive charge

$\boxed{m_p = 1840 m_e}$ $m_p = 1.673 \times 10^{-27}$ kg

Neutron: is a composite particle made up of three quark having no charge.

$m_n = 1.675 \times 10^{-27}$ kg

Nuclear force: The force that binds the nucleons (P+N) inside the nucleus is called nuclear force. It is the strongest fundamental force of nature. Its range $R \sim 10^{-15}$ m.



Nucleus representation: ${}^{A}_{Z}X$

$A \to N + Z$

$\boxed{N = A - Z}$

$A \to$ mass no
= no of nucleons (P+N)

$Z \to$ Atomic number
= no of Proton inside the nucleus.

Isotopes: Elements having same atomic no but diff atomic mass." It have same chemical properties but diff physical properties

e.g $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$, C^{12}_{6} C^{13}_{6} C^{14}_{6}

Isobar's:- A = same, Z = different | same physical properties, different chemical properties

e.g $^{3}_{1}H$ + $^{3}_{2}He$

Isotones:- Elements having same no of neutrons

e.g Cl^{37}_{17} + $^{39}_{19}K$, $^{3}_{1}H$ + $^{3}_{2}He$

Nuclear Masses:- Nuclear masses are determined by mass spectrograph and nuclear reaction techniques on unified mass scale in U also known as **amu** which is based on mass of C^{12}_{6} that is taken exactly as 12.00U.

$$1U = \frac{1}{12}\left[\text{mass of } C^{12}_{6}\right]$$

$$1U = \frac{1}{12}\left[\frac{12kg}{6.022\times10^{28}}\right]$$

$$1U = 1.6606\times10^{-27} kg$$

$$1kg = \frac{1U}{1.6606\times10^{-27}}$$

$$m_p = \frac{1.673\times10^{-27}}{1.6606\times10^{-27}}U = 1.00728U$$

$m_N = \frac{1.675\times10^{-27}}{1.6606\times10^{-27}} = 1.00867u$.

$m_e = \frac{9.1\times10^{-31}}{1.6606\times10^{-27}} = 0.0005u$.

MCQ.

$1u \longrightarrow$ Energy.

$E = mc^2$

$= 1.6606\times10^{-27}\times(3\times10^8)^2$

$E = 1.5\times10^{-10} J$

$E = \frac{1.5\times10^{-10}}{1.6\times10^{-19}} eV$

$\boxed{E = 931 MeV}$

$\boxed{1u = 931.5 MeV.}$

$E_p = 1.007284u \times 931.5 \frac{MeV}{u}$

$E_p = 938.2 MeV$.

α-decay. CIG.

$_Z^AX \longrightarrow {}_{Z-2}^{A-4}Y + {}_2^4He + Q$

daughter nuclei; K.E

$Q = [(m_x)_u - [(m_Y)_u + (m_{He})_u]] \times 931.5 \frac{MeV}{u}$

β-Decay: → fast moving electrons.

+β-Decay

P / N

$_Z^AX \rightarrow {}_{Z-1}^{A}Y + {}_{+1}^{0}\beta + \nu + Q$

P > N $\frac{P}{N} > 1$.

$_1^1H \longrightarrow {}_0^1n + {}_{+1}^{0}\beta + \nu + Q$

-β decay.

N / P

$_Z^AX \longrightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}\beta + \bar{\nu} + Q$

N > P

$_0^1n \longrightarrow {}_1^1H + {}_{-1}^{0}\beta + \bar{\nu} + Q$

e.g $^{10}_{6}C \rightarrow {}^{10}_{5}B + {}^{0}_{+1}\beta + \gamma + Q$.

e.g $^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta + \bar{\nu} + Q$

or

$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + \bar{\gamma} + Q$

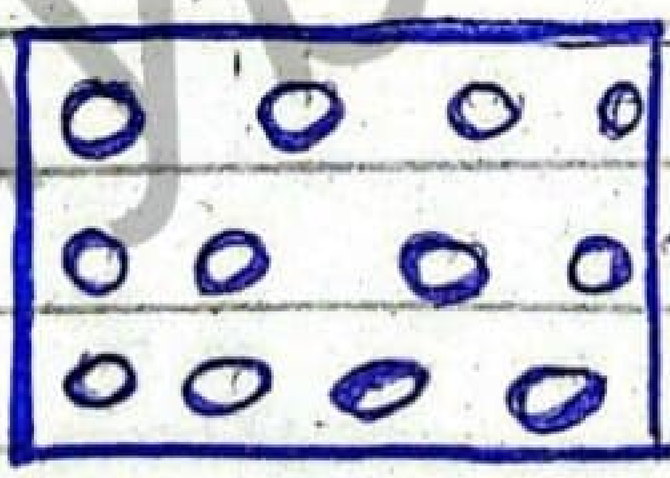
γ-decay: → charge less & mass less

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

e.g

$^{60}_{27}Co \longrightarrow {}^{60}_{27}Co + \gamma\text{-rays}$

Spontaneous & Random nature of nuclear decay:-



~ radio active element sample

We cannot tell which nuclei decay & when

Count rate $= \dfrac{\Delta N}{\Delta t}$ ← no of decay / per sec

$\dfrac{\Delta N}{\Delta t} \propto N$ — no of atoms

count rate ∝ no of radio nuclei present at any time t less & less but always some left.

Half Life: "The time during which half of the nuclei of radio active element decay is called half life."

Let N_o is the initial no of nuclei present in a sample at time $t=0$.

After first half life time no of nuclei undecayed $= N_u = \frac{N_o}{2}$

50%

After 2^{nd} half lifetime no of nuclei undecayed $N_u = \frac{N_o}{4} = \frac{N_o}{2^2}$

$= 25\%$

After 3rd halflife " " " $N_u = \frac{N_o}{2^3} = 12.5\%$

After 4th halflife " " $N_u = \frac{N_o}{2^4} = 6.25\%$

After 1^{st} half life time no of nucleoid decay

$= N_d = \left(N_o - \frac{N_o}{2}\right) = 50\%$

After 2nd halflife no of nucleoid decay $= N_d = N_o - \frac{N_o}{2^2}$

$= 75\%$

After 3^{rd} half life " " $N_d = N_o - \frac{N_o}{2^3}$ $= 87.5\%$

After 4^{th} half life " " $N_d = N_o - \frac{N_o}{2^4} =$

After n half life no of nuclei undecay $- N = \frac{N_o}{2^n}$.

After n-half life " " decayed $= N = N_o - \frac{N_o}{2^n}$

$= N_o\left(1 - \frac{1}{2^n}\right)$

$\therefore n = \frac{\text{Lifetime}}{\text{Half Life time}}$

∴ Half life doesnot depend on temperature & pressure. It depends only on nature of element.

Example: $N = 1000$ atom.

$t_{1/2} = 3$ years

$\therefore n = \frac{87}{3} = 27$

after 87 years $N_d = ?$

$$N_d = N_0\left(1 - \frac{1}{2^n}\right)$$

$$N_d = 1000\left(1 - \frac{1}{2^{27}}\right) = \_\_\_\_\_\_$$

*** Rate Law, decay rate:** The rate of disintegration per second is directly proportional to the no of atom present in a sample at any time t.

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

Activity:- No of atoms disintegrate per second is called activity.

$$A = \frac{\Delta N}{\Delta t} \propto -N$$

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

λ → decay constant

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

A → activity; λ → decay const; N → no of atom present in sample at anytime t

Unit ① Bq

1 Bq = 1 d/s

② Ci   1 Ci = 3.7×10^{10} Bq

③ 1 Rutherford = 10^6 Bq.

Exponent nature of radioactive decay

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

As we know that

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

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

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

Apply integration on both sides.

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

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

$$\boxed{\ln(N) = -\lambda t + C} \quad (1)$$

for Calculation of C put $\left.\begin{matrix} t = 0 \\ N = N_0 \end{matrix}\right]$ put in (1)

$$\ln N_0 = -\lambda(0) + C$$

$$\ln N_0 = C. \quad \text{put in eq (1)}$$

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

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

$$\ln \frac{N}{N_0} = -\lambda t$$

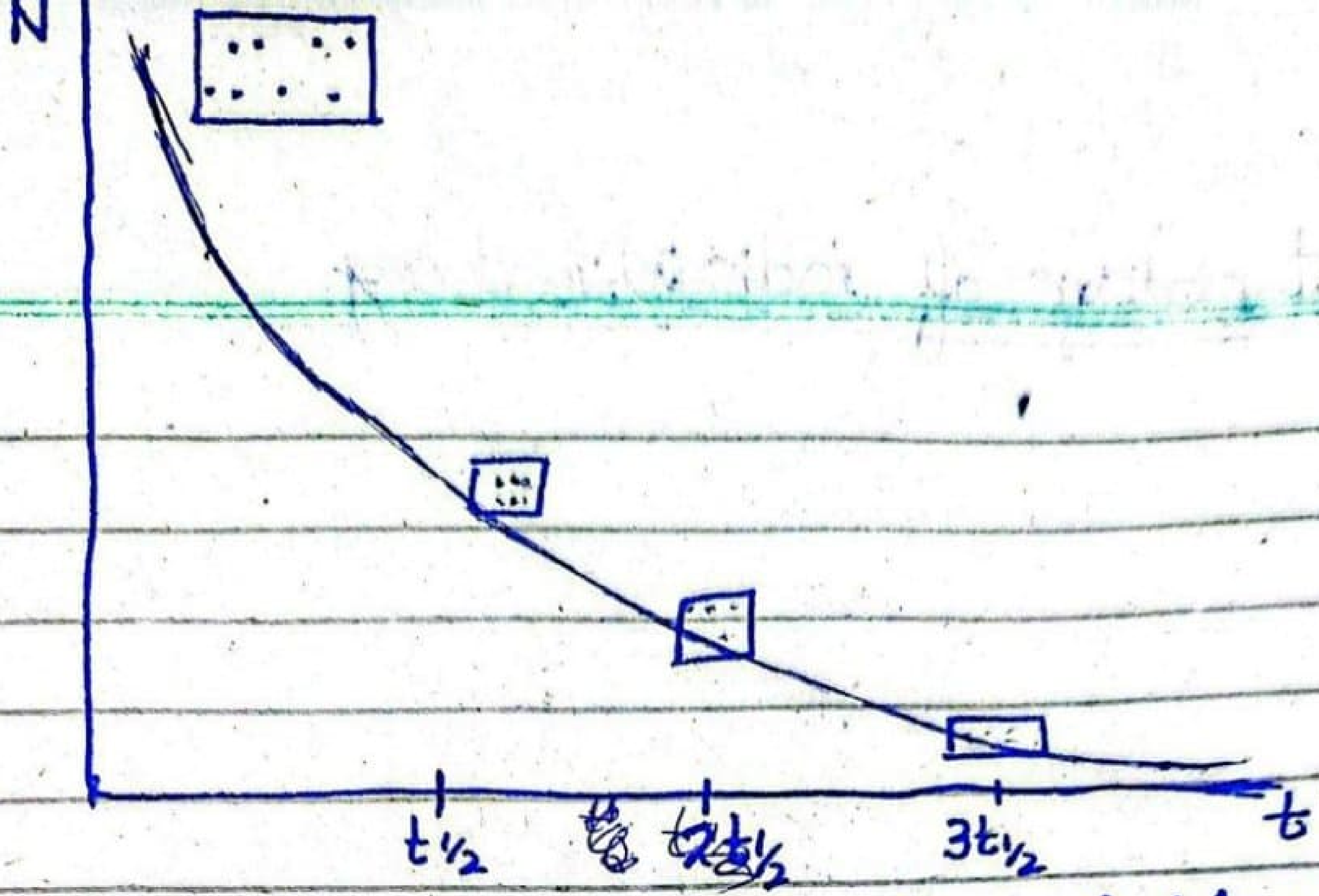
Taking exponent on both sides

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

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

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

CS CamScanner



* Relation b/w decay constant & half life :-

$$N = N_0 e^{-\lambda t} \quad \text{——} (1)$$

$$\left.\begin{array}{l} t = t_{1/2} \\ N = \dfrac{N_0}{2} \end{array}\right] \text{put in } (1)$$

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

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

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

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

Taking ln on bothsides

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

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

$$\lambda = \frac{\ln 2}{t_{1/2}} \qquad \text{Unit: } s^{-1}$$

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

Mean life time: $T^* = \frac{1}{\lambda}$

Reciprocal of decay constant

$$T^* = \frac{1}{\frac{0.693}{t_{1/2}}}$$

$$T^* = \frac{t_{1/2}}{0.693}$$

$$T^* = 1.44\, t_{1/2}$$

$$\boxed{T^* > t_{1/2}}$$

Assignment: 22.1

$m_T = 5.0083 \times 10^{-27}$ kg

$m_p = 1.672 \times 10^{-27}$ kg

$m_n = 1.675 \times 10^{-27}$ kg

$\Delta m = ?$

$\Delta m = (Zm_p + Zm_n) - m_{nucleu}$

$= [(1 \times 1.672 \times 10^{-27} + 2 \times 1.675 \times 10^{-27} \text{ kg})] - 5.0083 \times 10^{-27}$

$\boxed{\Delta m = 1.43 \times 10^{-29} \text{ kg}}$

Assignment 22.2

$m_n = 3.344 \times 10^{-27}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$m_n = 1.675 \times 10^{-27}$ kg

$\Delta m = [1 \times (1.673 \times 10^{-27}) + (1.675 \times 10^{-27})] - 3.344 \times 10^{-27}$

$= 4.0 \times 10^{-30}$ kg

$B.E = (4 \times 10^{-30})(3 \times 10^{8})^2 \times 6.242 \times 10^{18}$ eV

$= 2.25$ MeV

Assingment 22.3 :-

mass of N-13 = 2.1608×10^{-26}

$m_p = 1.007276u$

$m_n = 1.008665u$

$\Delta m = ((1.007276)7 + (1.008665)6) - 2.1608 \times 10^{-26}$

$= 13.102922u - 2.1608 \times 10^{-26}$

$= 13.102922 \times 1.66 \times 10^{-27} - 2.1608 \times 10^{-26}$

$= 1.52 \times 10^{-28} kg$

$E = 1.52 \times 10^{-28} \times (3 \times 10^{8})^2 = 1.368 \times 10^{-11} J$

$f = \frac{1.368 \times 10^{-11}}{13}$

$f = 1.0523 \times 10^{-12} J$

$f = \frac{1.0523 \times 10^{-12}}{1.6 \times 10^{-19}} = \boxed{6.58 MeV}$ Ans

Assingment 22.4

Mass of C-14 = 14.000u

Mass of N-14 = 14.00307 amu

mass of $\bar{e}$ = 0.0005486u

$Q = M_{C-12} - [M_N + M_e]$

$= 14.000 - [14.00307 + 0.0005486] \times 931.5 MeV$

$Q = -2.86 MeV$.

non spontaneous

Assingment 22.5

$N_o = 780$ $N_u = 780 - 240 = 540$

$\Delta N = 240$

$$\lambda = \frac{\ln N_o - \ln N}{t}$$

$$\lambda = \frac{\ln(780) - \ln(240)}{12}$$

$$= 0.3086 s^{-1}$$

$$A = \lambda N_o = (0.3085)(780)$$

$$= \boxed{24.02 Bq}$$

Assingment 22.6.

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

$$\lambda = \frac{0.693}{34920 sec} \Rightarrow \boxed{\lambda = 1.98 \times 10^{-5} s^{-1}}$$

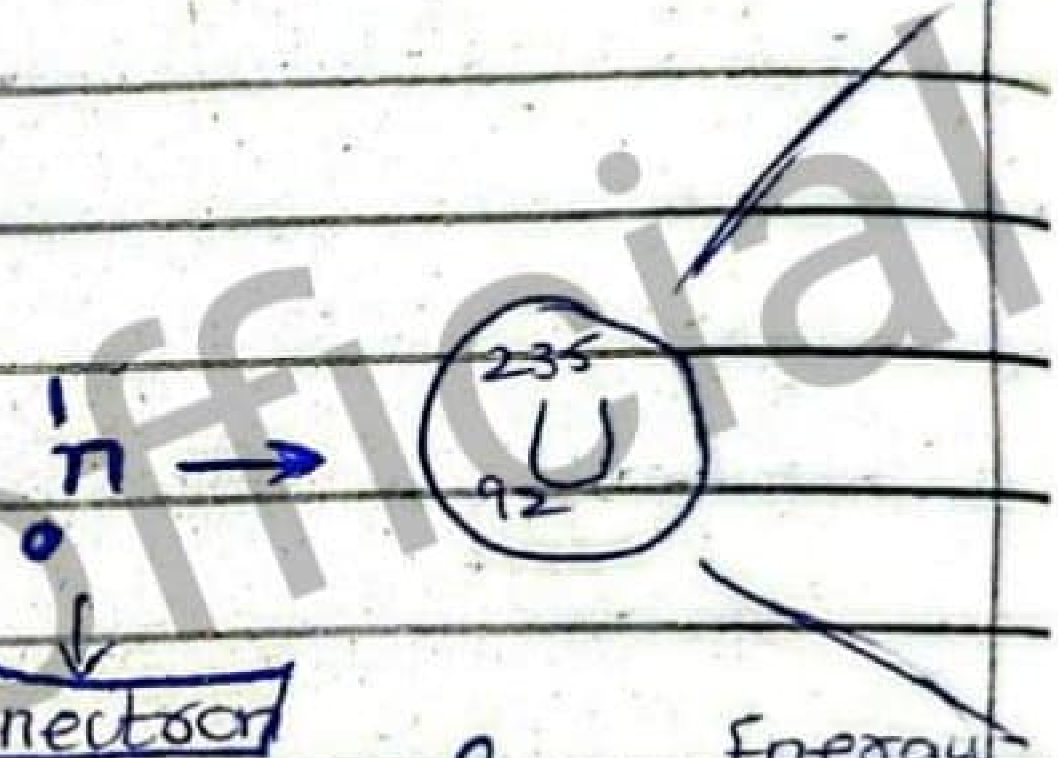
CH#22 Nuclear fission

(It is a type of nuclear reaction).

"The splitting of a heavy nucleus into two lighter nuclei of compareable masses along with release of large amant of energy is called nuclear fission".

$$a + X \longrightarrow f_1 + f_2 + b + Q.$$

- $a \rightarrow$ incident particle
- $X \rightarrow$ Target nucleus
- f_1 & $f_2 \rightarrow$ fission fragments
- $b \rightarrow$ smallest particle
- $Q \rightarrow$ nucleer energy



Discovery of nuclear fission:-

Otto-hahn and ~~fritz~~ straisman bombared thermal neutron on natural Uranium. They observed that when thermal neutron is bombared on $^{235}_{92}U$, it split into $^{141}_{56}Ba$ & $^{92}_{36}Kr$ along with 3 fast moving neutron and 200 MeV energy is released.

Ty Thermal neutron $\rightarrow$ 0.025eV

Energy

Slow electron energy 1ev ~ 10ev.

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + Q.$$

mass of $^{235}_{92}U$ = 235.0439 u	" " $^{1}_{0}n$ = 1.0087 u	Reactant = 236.0526 u
" " Ba = 140.9319 u	" " Kr = 91.8973 u	" " $3^{1}_{0}n$ = 3.00261 u ; Product = 235.8373 u

$Q = \left[\text{Mass of interacting Particle} - \text{Mass of product Particle}\right] \times 931.5 \frac{MeV}{u}$

$Q = [236.05261u - 235.8371u] \times 931.5 \frac{MeV}{u}$

$Q = 0.2153u \times 931.5 \frac{MeV}{u}$

$\boxed{Q = 200.5 MeV}$

$1g \longrightarrow U \longrightarrow 10^{19}$ atoms

Energy relased in fission of $1g U = 10^{19} \times 200.5 MeV$

$1 Kg \xrightarrow{U}$ fission

3000 ton $\longrightarrow$ burning of coal.

Binding energy per nucleon of $U^{235}_{92} = 7.6 MeV$

" " " ${}^{141}_{56}Ba + {}^{92}_{36}Kr = 8.5 MeV$

$Q = 8.5 - 7.6$

$\boxed{= 0.9 MeV}$

$Q = 0.9 MeV \times 235$

$\boxed{Q = 211 MeV}$

Fission Chain Reaction:- A self sustaining fission reaction is known as fission chain reaction.

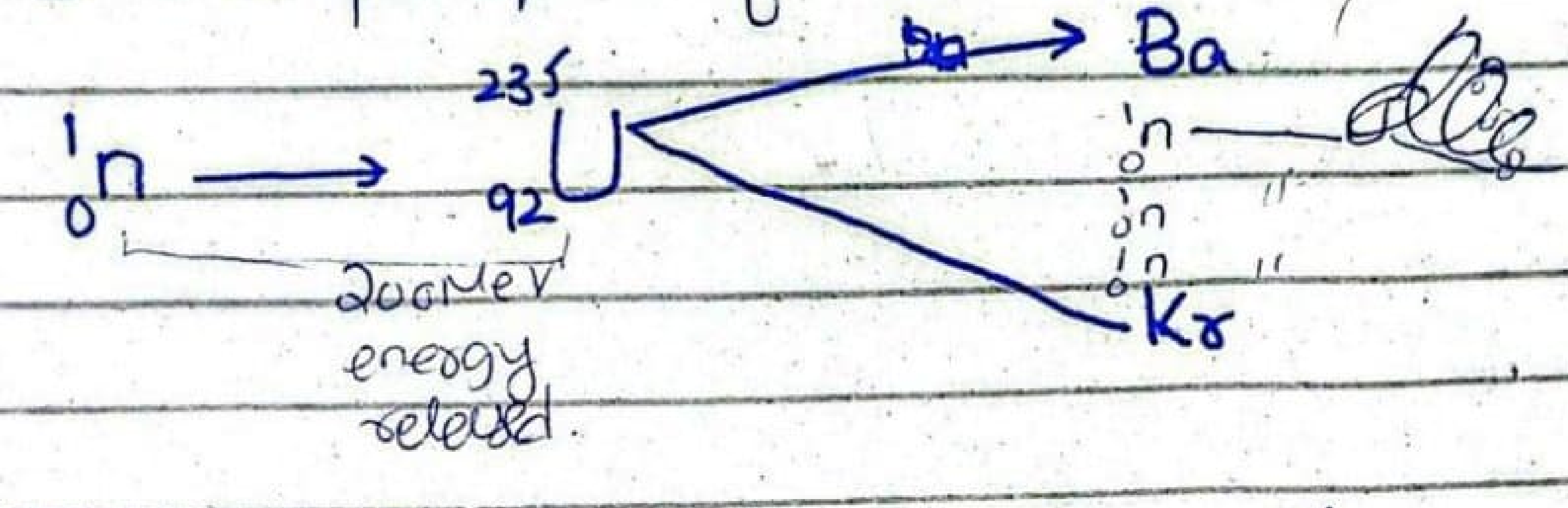
Types

1) Uncontrolled fission chain reaction.
2) Controlled fission chain reaction.

1) **Uncontrolled fission chain rxn:** If the rate of fission reaction increases with the passage of time then this is called

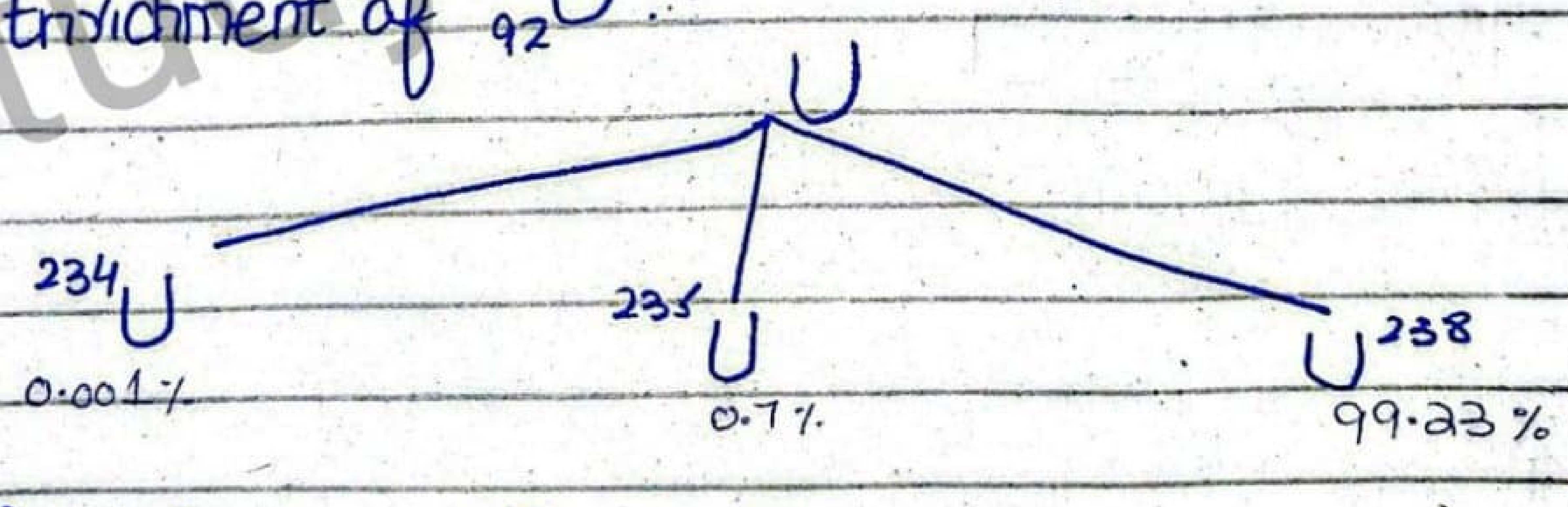
Critical mass: The min mass of uranium required to produce further fission rxn is called critical mass or critical volume.

Uncontrolled fission chain reaction. As a result of this reaction large explosion take place this is a principal of atomic bomb.



Controlled fission chain reaction:- If the rate of fission reaction remain constant with the passage of time then this type of reaction is known as controlled fission chain reaction. This is the principal of nuclear reactor.

Enrichment of $^{235}_{92}U$.



Critical mass: Def on top

U < Critical mass — fission rxn stop.

U > " — uncontrolled fission.

U = " — Controlled fission rxn

Nuclear fusion: when two or more lighter nuclei combine to form a heavy nucleus along with simultaneous release of energy is called nuclear fusion.

e.g $_1^1H + _1^1H \longrightarrow _1^2H$

Proton-Proton Cycle: $2\times\, _1^1H + _1^1H \longrightarrow _1^2H + e^+ + \nu + 0.42$ MeV

P P P n

$2\times\; e^+ + e^- \longrightarrow \gamma + \gamma + 1.02\ MeV$

$2\times\; _1^1H + _1^2H \longrightarrow _2^3He + \gamma + 5.4MeV$

$_2^3He + _2^3He \longrightarrow _2^4He + _1^1H + _1^1H + 12.86MeV$

4P 2N

$4\,_1^1H + 2e^- \longrightarrow _2^4He + 6\gamma + 2\nu + 26.7MeV$

MCQ which will release more energy fission or fusion:

$1U \longrightarrow 200MeV$

$236amu = 200MeV$

$1amu = \frac{200}{236}$

$= \boxed{0.85MeV}$

Nuclear Reactor (Pressurized Water Reactor).

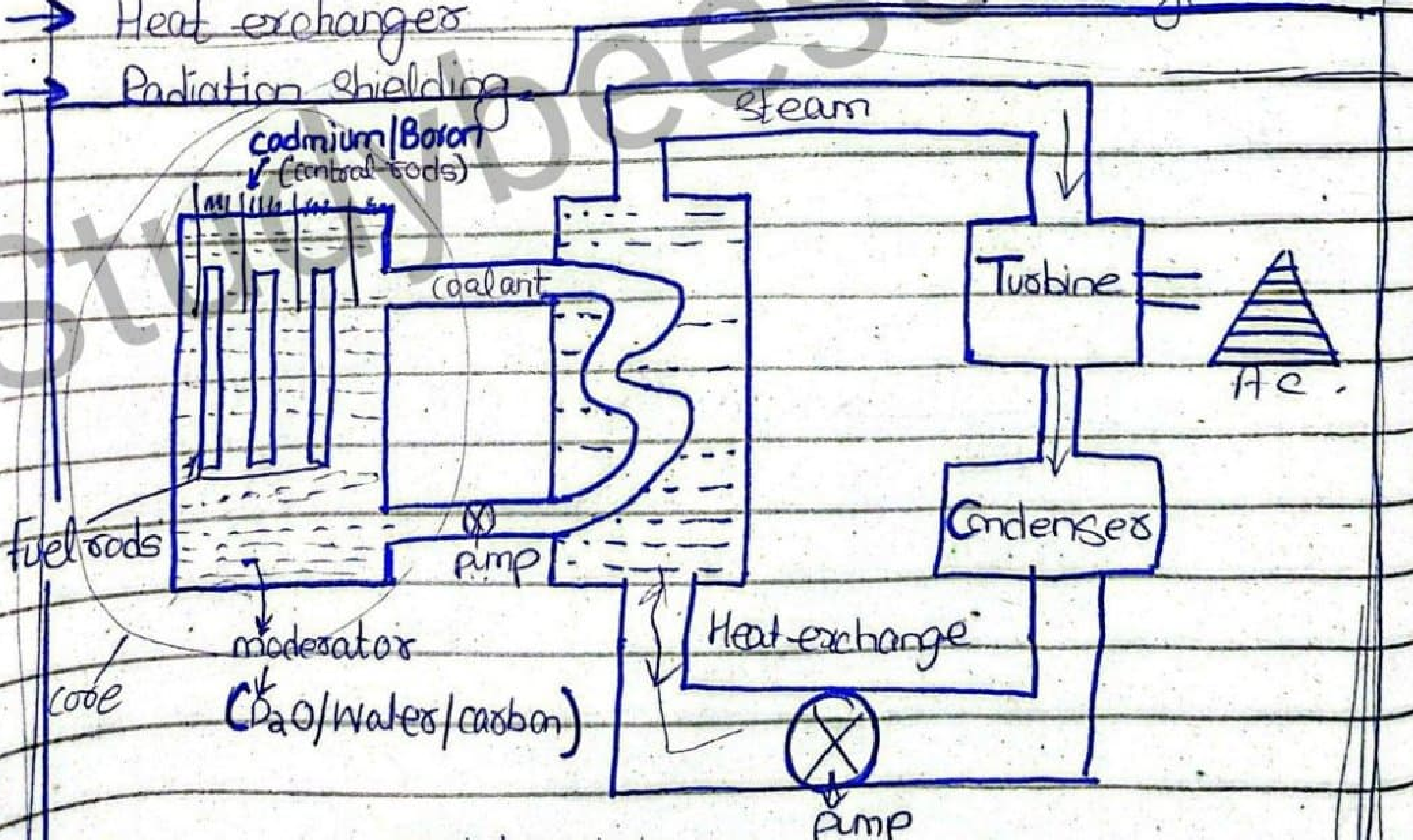
It is a device in which fissionable and non-fissionable material is used to produce nuclear energy for peaceful purpose.

→ Benefit of man kind.

Principle: The principle of nuclear reactor is control fission chain reaction.

Construction and working :- → Atomic fuel] → cylindrical rod ↓ enriched U^{235} ↓ Induces ↓ Fission chain reaction.

→ moderator → Thermalize fast moving neutron.
→ Control rods → core of nuclear reactor
→ Safety rod → absorb neutron.
→ Reflector → high reflection coefficient.
→ coolant → absorbs heat to maintain temp
→ Heat exchanger
→ Radiation shielding. / Shielding (lead wall)



Good moderator –
- High particle density.
- Low atomic weight.
- Low absorption coefficient.
- High scattering / Reflection coefficient.

Good Control rod → high absorption crosssection
→ low scattering coefficient

Safety rods are kept spare for safety purpose
∴ we shield core that minimizes the
leakage of neutron.
coolant → a good coolant has :- → High specific heat
capacity.
→ low viscosity.
→ High thermal conductivity.

Enrichment of Uranium-235 :-

U → gases

	^{234}U	U^{235}	$U^{238} \Rightarrow P_u$
abundance :	0.001%	0.7%	99.23%
		↓ Thermalized neutron ⇓ $\boxed{E = 0.025\,ev}$	↓ fast moving neutrons.

after enrichment 3-5%.

• we collect light U^{235} & side P_u^{238} (heavy) for enrichment of uranium.