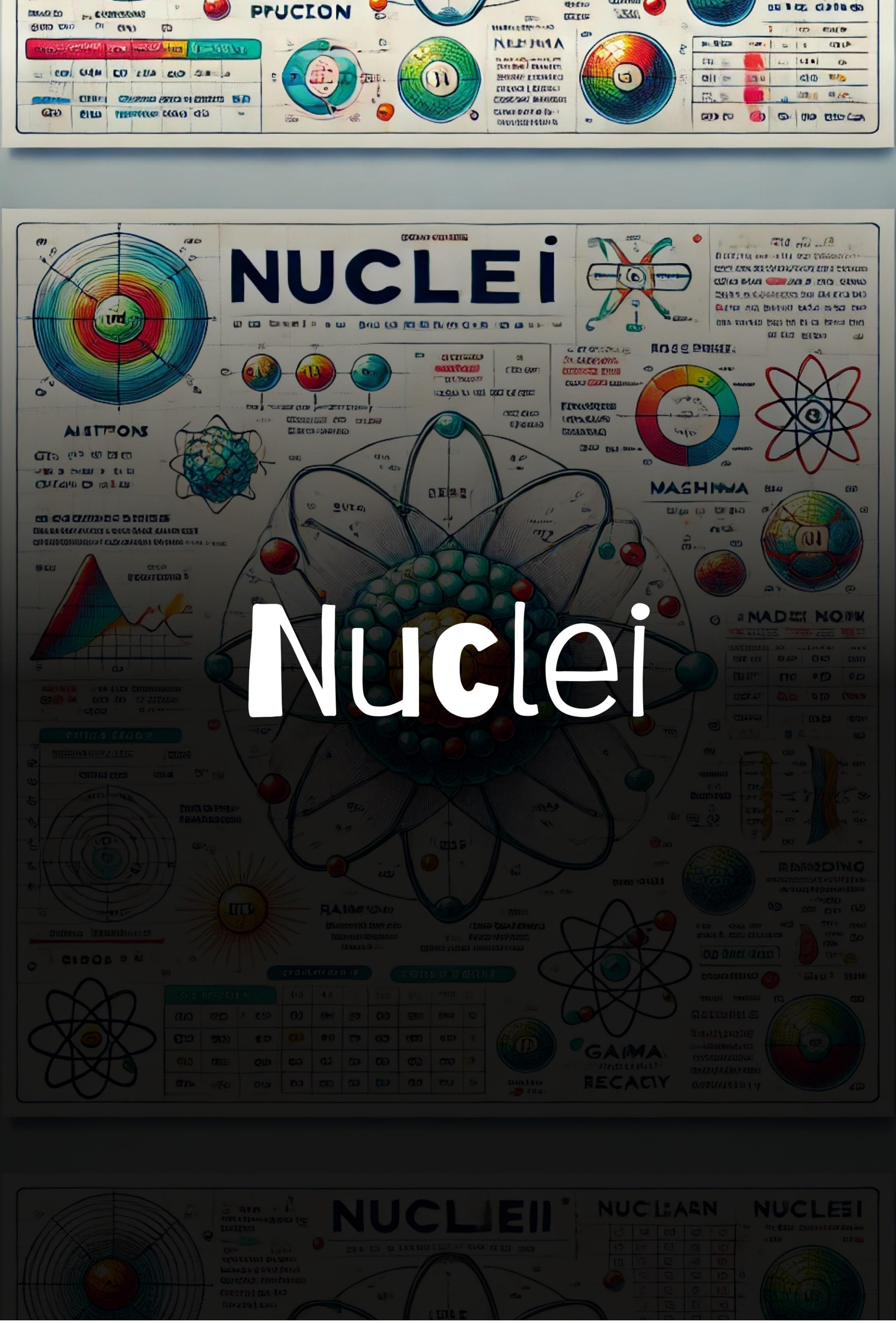


Nuclei

NUCLEAR PHYSICS

$_{Z}X^{A}$ A = mass number [no. of P + no. of N]

↳ atomic no. [Z = no. of proton]

electrons   positron
quarks
neutrino   Anti neutrino

→ Leptons (all are fundamental particles)

[Proton + Neutron]
↓
Nucleons
Hydrons
Baryons.

X ray ⟶ photon (EM wave)
Cathode ray / Beta particle → fast moving $e^{\ominus}$
Positron ⟶ anti particle of $e^{\ominus}$

$Q = +e^{-}$

$m = m_e$

Neutrino / Anti neutrino

↳ $Q = 0$

massless

mass <<<<< m_e

$m_p = 1.67 \times 10^{-27}$ kg $= 1.0073$ amu

$m_n = 1.67 \times 10^{-27}$ kg $= 1.0087$ amu

$m_e = 9.1 \times 10^{-31}$ kg

1amu $= 1.66 \times 10^{-27}$ kg $= \frac{{}_6C^{12}}{12}$

Rest - mass energy

$E = m_0 c^2$

↳ rest mass

Outside a nucleus ⇒ nutron is unstable but proton is stable

Q The energy equivalent of 0.5g of a substance is.

⇒ $E = m_0 c^2$

$= 0.5 \times 10^{-3} \times 9 \times 10^{16}$

$= 4.5 \times 10^{13}$ J

Q α-particle consists of
↳ 2 protons & 2 neutrons only

Q The energy equivalent of one atomic mass unit is.

⇒ $E = m_0 c^2$

$E = 1 amu\ c^2$

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

$= 1.66 \times 10^{-11} \times 9$ J

In eV

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

$\therefore E = \frac{\cancel{1.66 \times 10^{-11}}}{\cancel{1.6 \times 10^{-19}}} 10^8 \times 9 =$ 9315 $\times 10^8$ eV

931.5 MeV → $1 amu\ c^2 = 931.5$ MeV

MR_Ratta

Q Find rest mass of proton.

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

$= 1.0073$ amu c^2 $= 1.0073 \times 931.5 = 931.56$ MeV

NUCLER SIZE

A ⇒ mass no. = no. of nucleons = no. of P + no. of N.

Volume of nucleus ∝ mass no.

For nucleus to be stable

a) For light nuclei $\Rightarrow \frac{N}{Z} = 1$

b) For heavy nuclei $\Rightarrow \frac{N}{Z} > 1$ N = neutron no.

Volume $\propto$ mass no. A

$V \propto A$

$\frac{4}{3}\pi R^3 \propto A$

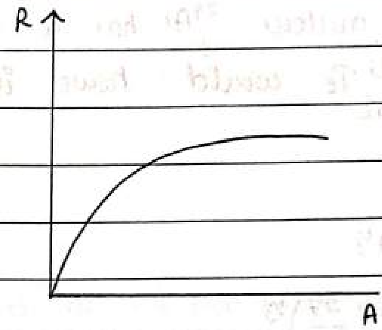
$$\boxed{R \propto A^{1/3}}$$

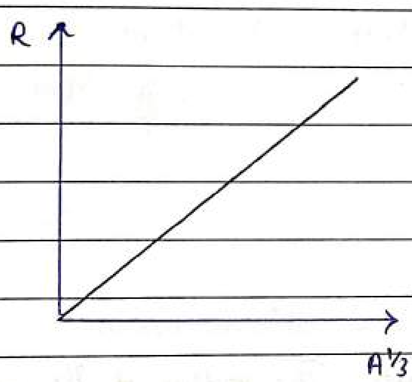
$R = R_0 A^{1/3}$

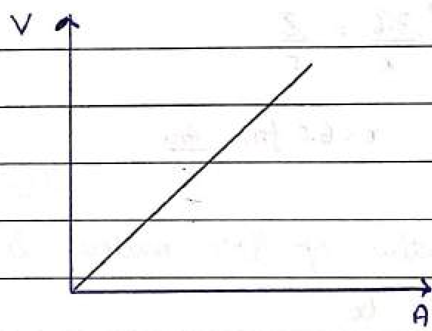
$\hookrightarrow R_0 (A=1) = 1.2\,fm$

$= 1.4\,fm$

$$\boxed{\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}}$$







Nuclear density

$\rho = \frac{\text{Mass of nucleus}}{\text{Volume}}$ Total mass of nucleus $= A m_p$ $(m_p \simeq m_n)$

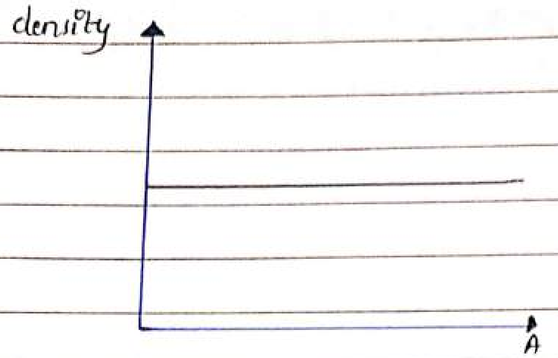
$\rho \Rightarrow \frac{A m_p}{\frac{4}{3}\pi r^3} = \frac{\cancel{A} m_p}{\frac{4}{3}\pi \cancel{A} R_0^3} = \frac{3 m_p}{4\pi R_0^3} \approx 10^{17}\ kg/m^3$

does not depend on mass no.

is same for every element.

No. of nucleons per unit volume = $\frac{\text{density}}{\text{mass of one nucleon}}$

$\Rightarrow \frac{10^{+17}}{1.67 \times 10^{-27}} = 10^{44}$ nucleons/m^3



Q If the nucleus $^{27}_{13}Al$ has a nuclear radius of about 3.6 fm then $^{125}_{52}Te$ would have its radius approximately as.

Ans $r \propto A^{1/3}$

$\frac{3.6}{x} = \left(\frac{27}{125}\right)^{1/3}$

$\frac{\cancel{3.6}^{1.2}}{x} = \frac{\cancel{3}}{5}$

$x = 6.0$ fm Ans

Q Radius of ^4_2He nucleus is 3 fermi. The radius of $^{32}_{16}S$ nucleus will be

$\Rightarrow$ $\left(\frac{4}{32}\right)^{1/3} = \frac{3}{x}$

$\frac{1}{2} = \frac{3}{x}$

$x = 6$ fermi

Q The volume occupied by an atom is greater than the volume of the nucleus by a factor of about.

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$\Rightarrow$ $\frac{V_{atom}}{V_{nucleus}} = \frac{\frac{4}{3}\pi (10^{-10})^3}{\frac{4}{3}\pi (10^{-15})^3} = \frac{10^{-30}}{10^{-45}} = 10^{15}$

Q The radius of germanium (Ge) nuclide is measured to be twice the radius of $^{9}_{4}Be$. The no. of nucleons in Ge are.

Ans $\frac{2 r_{Ge}}{r_{Be}} = \left(\frac{x}{9}\right)^{1/3}$

$2 \times 9^{1/3} = x^{1/3}$

$8 \times 9 = x$

$x = 72$ Ans

Q Two nuclei have their mass no. in the ratio of 1:3. The ratio of their nuclear densities would be.

$\Rightarrow$ $\frac{A_1}{A_2} = \frac{1}{3}$

nuclear densities would remain same

Q M_n and M_p represent the mass of neutron and proton respectively. An element having mass M has N neutrons and Z protons, then the correct relation will be.
★★★
★★

a) $M > \{N \cdot M_n + Z M_p\}$

b) $M < \{N \cdot M_n + Z \cdot M_p\}$

c) $M = N \cdot M_n + Z \cdot M_p$

d) $M = N\{M_n + M_p\}$

Nuclear binding energy / Mass defect

$\Delta M = [Z m_p + (A-Z) m_n - M(\text{Nuclear})]$

↓

mass defect

$\frac{BE}{A}$ = B.E per nucleons represents stability of nucleus

$B.E. = \Delta m \times c^2$

↳ Energy required to break the nucleus into individual nucleons

this is not a stored energy, this is required energy to break nucleus

$\text{Nucleus} \xrightarrow{\text{mass} \uparrow} Z + (A-Z)$

energy given to break the nucleus is converted into mass

Nuclear stability $\propto \frac{B.E}{A}$

${}_6X^{12} \rightarrow BE = 36\ eV \qquad \frac{BE}{A} = \frac{36}{12} = 3\ eV$

${}_4Y^{6} \rightarrow BE = 24\ eV \qquad \frac{BE}{A} = \frac{24}{6} = 4\ eV$

Y is more stable than X

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Q Binding energy of $_2He^4$ and $_3Li^7$ are 27.37 MeV and 39.3 MeV respectively. Which of the two nuclei is more stable?

ANS $\left(\frac{B.E}{A}\right)_{He} = \frac{27.37}{4} = 6.8\,eV$

$\left(\frac{B.E}{A}\right)_{Li} = \frac{39.3}{7} = 5.6\,eV$

He is more stable than Li

Q The mass of proton is 1.0073 u and that of neutron is 1.0087 u (u = atomic mass unit). The binding energy of $_2He^4$ is (Given mass of helium nucleus = 4.0015 u)

ANS $BE = \Delta m\, c^2$

$\Delta m = [2 \times 1.0073 + 2 \times 1.0087 - 4.0015]$

$= 2.0146 + 2.0174 - 4.0015$

$= 4.0320 - 4.0015$

$= 0.0305\,u$

$BE = \Delta m\, c^2$

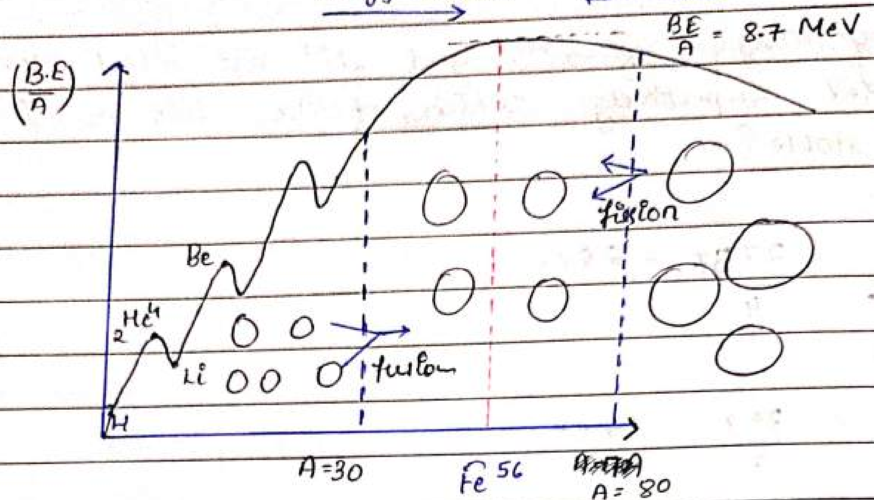
$= 0.0305 \times u c^2 = 0.0305 \times 935.1\,MeV$

$= \frac{3}{100} \times 935.1\,MeV \approx \frac{2805.3}{100}\,MeV = 28.053\,MeV$

Ans

$^{2}H = \frac{BE}{nucleon} = 1.1\,MeV$ $\quad$ $^{238}U \Rightarrow \frac{BE}{nucleons} = 7.6$

(Heavy hydrogen)



$\left(\frac{BE}{A}\right)$ 1st increases then decreases by increasing mass number.

$\boxed{30 < A < 80} \rightarrow$ stable nuclei.

Q The average binding energy per nucleon of a nucleus is of the order of

A) 8eV

B) 8J

C) 8keV

D) 8MeV

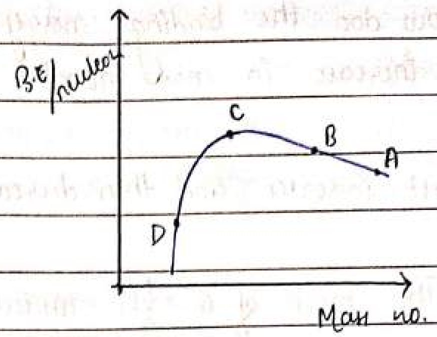
Q Binding energy per nucleons versus mass number curve for nuclei is shown in the figure. A, B, C and D are four nuclei indicated on the curve. The process that would release energy is?

a) $C \rightarrow 2D$

b) $A \rightarrow 2D$

c) $A \rightarrow 2C$

d) $B \rightarrow C + D$



Q Nucleus A divides into two nuclei B and C in a fission process, their binding energy being E_a, E_b and E_c respectively. Then

a) $E_b + E_c > E_a$

b) $E_b + E_c < E_a$

c) $E_b + E_c = E_a$

(d) $E_b - E_c = E_a$

Q Binding energy per nucleon curve as a function of atomic mass number has a sharp peak for Helium nucleus. We can conclude from this that helium nucleus

a) Is very stable

(b) Is radioactive

c) Can easily be broken

d) Can be used as fissionable material.

Q The mass no. of a nucleus is.

a) Always less than atomic no.

b) Always more than its atomic no.

c) Sometimes equal to its atomic no.

d) Sometimes less than and sometimes more than its atomic number.

Q How does the binding energy per nucleon vary with the increase in mass number.

→ First increases and then decreases with increase in mass number.

Q The mass of a $^{7}_{3}Li$ nucleus is 0.042 u less than a sum of the masses of all its nucleons. The binding energy per nucleon of $^{7}_{3}Li$ nucleus is nearly.

Ans $\Delta m = 0.042u$

$B.E = \Delta m c^2$

$= 0.042 \times 935.1$ MeV

$= 39.2742$ MeV

$\frac{B.E}{nucleon} = \frac{\cancel{39.2742}\ 5.6}{\cancel{7}}$ MeV $= 5.6$ MeV Ans

Q If $M(A;Z)$, M_p and M_n denote the masses of the nucleus $^{A}_{Z}X$, proton and neutron respectively in units of u and BE represents its binding energy in MeV, then.

a) $M(A;Z) = ZM_p + (A-Z)M_n - BE$

(b) $M(A,Z) = ZM_p + (A-Z)M_n + BE/c^2$

c) $M(A,Z) = ZM_p + (A-Z)M_n - BE/c^2$

d) $M(A,Z) = ZM_p + (A-Z)M_n + BE$

Q Energy released in nuclear fission is due to

⇒ total binding energy of fragments is more than the binding energy of parental element.

Q value of the Nuclear Reaction.

Reactant → Product

$$A + B \longrightarrow C + D + \underset{\text{released energy}}{Q}$$

$$Q = [m(A) + m(B) - m(C) + m(D)] \times c^2$$

If $Q = +ve$ then energy is released

$Q = -ve$ then energy is absorbed.

Case-1

$m(A+B) > m(C+D)$

Q = released energy $= +ve$

Stability ↑

Case-2

$m(A+B) < m(C+D)$

Q = absorbed

$Q \Rightarrow -ve$

Stability (↓)

Case-3

$BE(C+D) > BE(A+B)$

energy released

Case-4

$BE(C+D) < BE(A+B)$

energy absorbed.

$$\boxed{Q = BE(C+D) - BE(A+B)}$$

Q Consider the nuclear reaction

$$X^{200} \rightarrow A^{10} + B^{190}$$

If the binding energy per nucleon for X, A and B is 7.4 MeV, 8.2 MeV and 8.2 MeV respectively, then the amount of the energy released is.

→ $Q = [BE(A) + B(B) - BE(x)]$

$\Rightarrow$ ~~82+82−7.4~~ $8.2 \times 10 + 8.2 \times 190 - 200 \times 7.4$

$= 82 + 1558 - 1480$

$= 1640 - 1480$

$= 160 \text{ MeV}$ Ans

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Q The binding energy per nucleon of ^7_3Li and ^4_2He nuclei are 5.60 MeV and 7.06 MeV respectively. In the nuclear reaction $^7_3Li + ^1_1H \longrightarrow ^4_2He + ^4_2He + Q$. The value of released energy Q is.

Ans
$Q = [2\,BE(He) - (BE(Li) + BE(H))]$
$Q = [2 \times 4 \times 7.06 - 7 \times 5.60]$
$Q = [8 \times 7.06 - 39.2]$
$= 56.48 - 39.2$
$= 17.28$ MeV

Q The binding energy per nucleon for a deutron and an α particle are x_1 and x_2 respectively. The energy Q released in the reaction is.

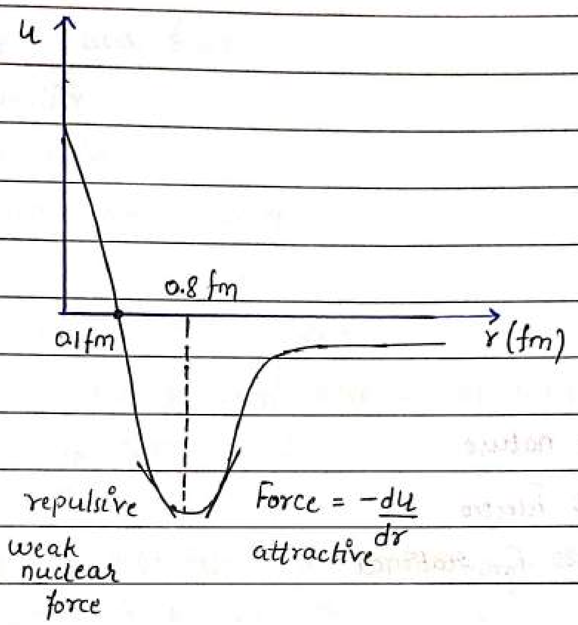
$^2H_1 + ^2H_1 \longrightarrow ^4He_2 + Q$ is

a) $4(x_1+x_2)$
b) $4(x_2-x_1)$
c) $2(x_2+x_1)$
d) $2(x_1+x_2)$

$Q = 4x_2 - 2 \times 2x_1$
$= 4(x_2-x_1)$

NUCLEAR FORCE

Strongest force, non-conservative force, attractive, charge independent, short range, does not follow inverse square law, saturation in nature, mediates by meson, spin dependent, equally acts b/w proton & neutron, non conservative.



Strong nuclear force
range = 10^{-15}m
attractive

Weak nuclear force [shortest range force]
→ range = 10^{-16}m
repulsive in nature
mediated by Boson

Q If the nuclear force between two protons, two neutrons and between proton and neutron is denoted by F_{pp}, F_{nn} and F_{pn} respectively, then.

a) $F_{pp} \approx F_{nn} \approx F_{pn}$
b) $F_{pp} \neq F_{nm}$ and $F_{pp} = F_{nm}$
c) $F_{pp} = F_{nm} = F_{pn}$
d) $F_{pp} \neq F_{nm} \neq F_{pn}$

Q Which of the following relation is correct for net force b/w two protons, two neutrons, proton and neutron inside nucleus

a) $F_{pp} = F_{nn} = F_{pn}$
b) $F_{pp} < F_{pn} = F_{nn}$
c) $F_{pp} > F_{pn} = F_{nn}$
d) $F_{pp} < F_{nn} < F_{pn}$

Nuclear force

Strongest force in nature

$F_{nuclear} = 100\ F_{electro}$

$F_{nuclear} = 10^{39}\ F_{gravitational}$

Charge independent

$F_{pn} = F_{nn} = F_{pp}$

If distance is greater than 10^{-15} m then $F_{electro} > F_{nuclear}$

Forces

Fundamental force		Derived force
	Gravitational force	Friction
	Electromagnetic force	Tension
	Strong nuclear	viscous
	Weak nuclear	spring

Weak nuclear force

- Range $= 10^{-16} m = 0.1 fm$ or less
- this is essential otherwise the whole nucleus would collapse.
- One should not conclude that nuclear force are repulsive, but they are always attractive.

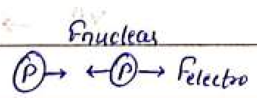
Nature of nuclear force

a) always attractive
b) always repulsive
c) May attractive and repulsive

They show saturation property
All nucleons does not exert force on all other nucleons, only on nucleons lying closest to it.

Q Two nucleons are at a separation of $1 \times 10^{-15} m$. The net force between them is 'F_1', if both are protons, F_2 if both are neutrons and F_3 if one is a proton and other is a neutron. In such a case:-

⇒ $F_1 < F_2 = F_3$



Q When two nuclei of mass X and Y respectively fuse to form a nucleus of mass m with the liberation of some energy then.

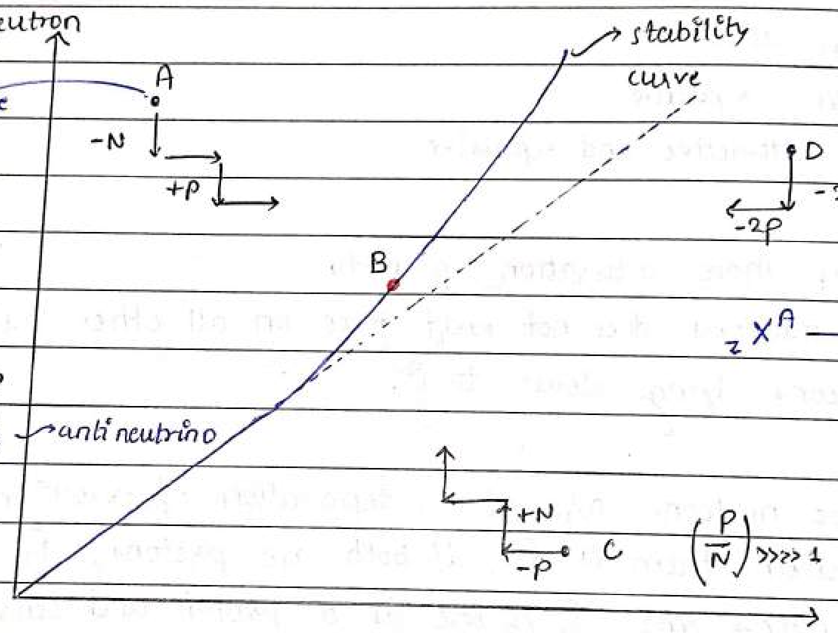
⇒ $X + Y > m$

Q In a nuclear fusion, if the energy released then.

$BE_{products} > BE_{reactants}$

Q The nuclear force between two nucleons is explained by

→ Meson exchange theory



A is unstable
- N >>> P
- $\left(\frac{N}{P}\right) >>> 1$

$N \rightarrow P + e^-$

β^- decay

${}_{Z}X^A \rightarrow {}_{Z+1}Y^A + e^{\theta} + \bar{\nu}_e$ → anti neutrino

atomic no increases by one but mass no. remains same

Q → energy released

Unstable due to (A>>>1)

α decay (A>>>1)

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

↓ α particle

$\left(\frac{P}{N}\right) >>> 1$

$P \rightarrow N + e^+$

β^+ decay (positron)

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

Atomic no. decreases by one but mass no. remains same.

Q → energy released

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⇒ β decay → β^- decay manenge
⇒ γ decay → energy released → in form of photon.
after α-β decay — mass no and atomic no same

Q After 1α and $2\beta^-$ emission.

⇒ $A-4 \longrightarrow A-4$ mass no. decreases by 4
$\underbrace{Z-2}_{\alpha \text{ decay}}\ +1\ +1 \longrightarrow Z$

For the light stable nucleide $N = Z$, so that $\frac{N}{Z} = 1$ for $A > 20$, but for heavier nuclide $\frac{N}{Z}$ increase and becomes 1.6 for the heaviest stable nuclei.

No nuclei with $Z > 83$ or $A > 209$ is stable.

Q If a heavy nucleus has N/Z ratio higher than that required for stability then.

a) It emits β^-
b) It emits β^+
c) It emits α particle

Q Complete the equations for the following fission process

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{38}Sr^{90} + \ldots$$

a) ${}_{57}X^{142} + 3\,{}_{0}n^{1}$ (d) ${}_{54}X^{142} + {}_{0}n^{1}$
b) ${}_{54}X^{145} + 3\,{}_{0}n^{1}$
c) ${}_{54}X^{143} + 3\,{}_{0}n^{1}$

Always check by mass no. because it is always balanced not atomic no.

Q A radioactive nucleus undergoes a series of decay according to the scheme

$$_{97}X^{192} \xrightarrow{\alpha} Y \xrightarrow{\beta^-} Z \xrightarrow{\alpha} A \xrightarrow{\gamma} B$$

mass no. and atomic no. of B are.

⇒ $192-4+0-4 = 192-8 = 184$ Ans

$97-2+1-2 = 94$ Ans

Q A nucleus ^m_nX emits one α particle and two β particles. The resulting nucleus is.

a) $^{m-4}_{n-2}Y$

b) $^{m-6}_{n-4}Z$

c) $^{m-6}_{n}Z$

d) $^{m-4}_{n}X$

Q In the given reaction

$$_ZX^A \longrightarrow {}_{Z+1}Y^A \longrightarrow {}_{Z-1}K^{A-4} \longrightarrow {}_{Z-1}K^{A-4}$$

a) α, β, γ

b) β, α, γ

c) γ, α, β

d) γ, α, β

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Q What is the particle x in the following nuclear reaction?

$$^{9}_{4}Be + ^{4}_{2}He \longrightarrow ^{12}_{6}C + x?$$

a) Electron
b) Proton
c) Photon
d) Neutron

Q For the given reaction, the particle X is

$$_{6}C^{11} \longrightarrow {}_{5}B^{11} + \beta^{+} + X$$

positron
↓
anti particle of e^{0}

a) Neutron
b) Anti-neutrino
c) Neutrino
d) Proton

Q A (hypothetical) radioactive substance undergoes decay according to the scheme

$$_{82}X^{194} \xrightarrow{\alpha} y \xrightarrow{\beta^-} z \xrightarrow{\gamma} L \xrightarrow{4\beta^+} M$$

⇒ $194 - 4 = 190 = A$

$82 - 2 + 1 - 4 = 77 = Z$

Q A radioactive nuclei of initial mass number A and atomic number Z emits 2α particle, $2\beta^-$ particle and 3 positron. The number of neutrons in the final nucleus will be.

⇒ $A - 8 = A - 8$

$Z - 4 - 1 = Z - 5$

no. of neutrons ⇒ $A - 8 - Z(+5)$

⇒ $A - Z - 3$ Ans

Q When $_{80}Th^{228}$ gets converted into, $_{83}Bi^{212}$, then the number of α and β- particle emitted will be respectively

a) 4α, 7β
b) 4α, 1β
c) 8α, 7β
d) 4α, 4β

Q $X\ (n, \alpha)\ {}^{7}_{3}Li$, then X will be

a) $^{10}_{5}B$
b) $^{9}_{5}B$
c) $^{11}_{4}Be$
d) $^{7}_{2}He$

→ $X + n \longrightarrow \alpha + {}^{7}_{3}Li$

Q value in α decay

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

parent nuclei   daughter nuclei

Q → released energy shared by daughter nuclei and α particle

$$Q = [m(X) - m(Y) - m(\alpha)] \times c^2$$

$$Q = [BE(Y) + BE(\alpha) - BE(X)]$$

↓ energy released for stability

$$\boxed{KE_{\alpha} + KE_{D} = Q} \quad -①$$

$$\underset{\text{rest}}{(X)} \xrightarrow{F_{ext}=0} \overset{\leftarrow}{\underset{P_y}{}}(Y) + (\alpha) \rightarrow P_\alpha$$

$P=0$

$F_{ext}=0$

$P_i = P_f$

$0 = \vec{P_\alpha} + \vec{P_y}$

$\vec{P_y} = -\vec{P_\alpha}$

$|\vec{P_y}| = |\vec{P_\alpha}|$

$KE \propto \frac{1}{m}$ (P=constant)

$\frac{KE_y}{KE_\alpha} = \frac{4\cancel{m_p}}{(A-4)\cancel{m_p}} = \frac{4}{A-4}$ —(1)

$KE_\alpha > KE_y$

$KE_\alpha + KE_D = Q$ —(1)

$KE_\alpha + \left(\frac{4}{A-4}\right) KE_\alpha = Q$

$KE_\alpha\left(\frac{A\cancel{-4}\cancel{+4}}{A-4}\right) = Q$

$\boxed{KE_\alpha = Q\left(\frac{A-4}{A}\right)}$

$\boxed{KE_D = \frac{4Q}{A}}$

Q $^{238}U \longrightarrow {}^{234}Th + \alpha$

If rest mass (in amu = 238.068) Th = 234.032 and α = 4.0020 then find

a) Q value

b) KE of α

a) $\Rightarrow$ $[238.068 - 234.032 - 4.0020]$ amu c^2

$\Rightarrow$ $[472.10 - 4.0020]$ amu c^2

$\Rightarrow$ $[468.098]$ amu c^2

$\Rightarrow$ 468.098×931.5 MeV $= Q$

$KE_\alpha \Rightarrow \left(\frac{A-4}{A}\right)Q \Rightarrow \frac{Q}{238} \times 234$ Ans

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Q A nucleus of ${}_{84}Po^{210}$ originally at rest emit α particle with speed v. Recoil speed of the daughter nucleus is,

$\Rightarrow$ $\vec{P}_y = \vec{P}_\alpha$

$m_y v' = m_\alpha v$

$(A-4) v' = 4v$

$v' = \frac{4v}{A-4} = \frac{4v}{206}$

Q A nucleus of mass 220 amu in free state decays to emit an α particle. Kinetic energy of the α particle emitted is 5.4 MeV. The recoil energy of the daughter nucleus is.

$\Rightarrow$ $\frac{KE_\alpha}{KE_D} = \frac{A-4}{4} = \frac{216}{4}$

$KE_D = \frac{\cancel{4}}{\cancel{216}_{54}} \times 5.4 \text{ MeV} = 0.1 \text{ MeV}$ Ans

Q A nucleus ${}^{220}X$ at rest decays emitting an α particle. If energy of daughter nucleus is 0.2 MeV. Q value of the reaction is.

ANS $KE_D = \frac{4Q}{A}$

$KE_D = 0.2 \text{ MeV}$

$Q = \frac{0.2 \times 2220}{4} = 11 \text{ MeV}$ Ans

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Q value of β^- decay

$$_{Z}X^{A} \longrightarrow {}_{Z+1}Y^{A} + e^{\ominus} + \bar{\nu}_e \quad —①$$

$$n \longrightarrow p + e^{\ominus} + \bar{\nu}_e \quad —②$$

Q in term of ①

mass of nuclei

$$Q = [(m_{Z}X^{A}) - m[_{Z+1}Y^{A}] - m_e] \times c^2 \quad \text{Ans}$$

Q in term of ②

$$Q = [m(n) - m(p) - m(e)] \times c^2 \quad \text{Ans}$$

Q value in a Beta decay in terms of atomic mass unit.

$$Q = \left([M({}_{Z}X^{A}) - m_e \times Z] - [M({}_{Z+1}Y^{A}) - m_e(Z+1) + m_e] \right) c^2$$

atom mass

$$Q = \left\{ [M({}_{Z}X^{A}) - \cancel{Zm_e}] - [M({}_{Z+1}Y^{A}) - \cancel{Zm_e} - \cancel{m_e} + \cancel{m_e}] \right\} c^2$$

$$Q = \left\{ M({}_{Z}X^{A}) - M({}_{Z+1}Y) \right\} \times c^2$$

atomic mass

β^+ decay

A → same

Z → decrease by 1

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

$$Q = \left\{ [m(_Z X^A)] - [m(_{Z-1}Y^A) + m_e] \right\} \times c^2$$

$\downarrow$

nucleus mass

$$Q = \left\{ [M(_Z X^A) - Zm_e] - [M(_{Z-1}Y^A) \mp (Z-1)m_e + m_e] \right\} \times c^2$$

$$Q = \left\{ [M(_Z X^A) - Zm_e] - [M(_{Z-1}Y^A) \mp Zm_e + \cancel{m_e} + \cancel{m_e}] \right\} \times c^2$$

$$Q = [M(_Z X^A) - Zm_e - M(_{Z-1}Y^A) - Zm_e] \times c^2$$

$$Q = [M(_Z X^A) - M(_{Z-1}Y)^A - 2Zm_e] \times c^2$$

$\downarrow$

atomic mass

$$Q = \left\{ m(_Z X^A) - [m(_{Z-1}Y^A) + m_e] \right\} \times c^2$$

$\downarrow$

nucleus mass

$$Q = \left\{ [M(_Z X^A) - Zm_e] - [M(_{Z-1}Y^A) - (Z-1)m_e + m_e] \right\} \times c^2$$

$$Q = \left\{ M(_Z X^A) - \cancel{Zm_e} - M(_{Z-1}Y^A) + \cancel{Zm_e} - m_e - m_e \right\} \times c^2$$

$$Q = \left\{ M(_Z X^A) - M(_{Z-1}Y^A) - 2m_e \right\} \times c^2$$

$$Q = \left\{ M(_Z X^A) - M(_{Z-1}Y^A) - 2m_e \right\} \times c^2$$

$\downarrow$

mass of atom

Neutrino

$\downarrow$

massless and

chargeless

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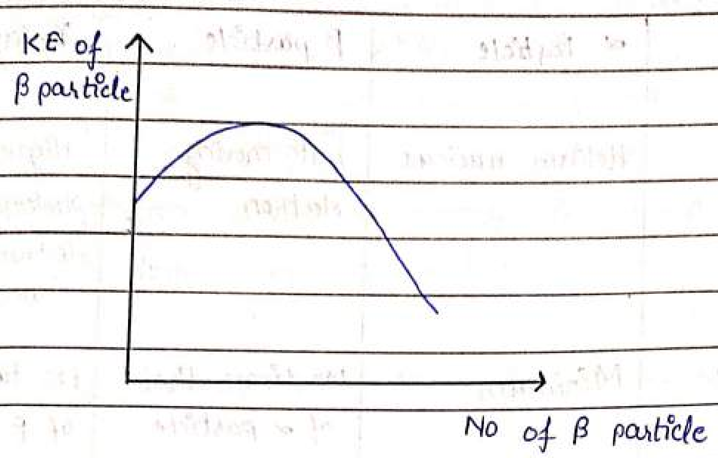


m (Daughter nuclei) >>> $m_{e^\ominus}$

$KE_{e^\ominus} \approx Q$ = KE of Beta particle
↓
experimentally

RADIOACTIVITY

(i) α decay ⇒ Helium nucleus $_2He^4$ is emitted (α-particle)
(ii) β decay → Electron or positron are emitted in β decay
(iii) γ decay → Photons of high energy are emitted
(iv) $e^\ominus$ capture → Proton + $e^\ominus$ → $_0n^1 + \nu_e$

Property	α - Particle	β particle	γ - Rays
Nature	Helium nucleus	Fast moving electron	Highly energetic photons or electromagnetic waves.
Penetrating Power	Minimum	100 times that of α particle	100 times that of β particle
Ionising power	100 times that of β particles	100 time that of γ particles	Minimum
Charge	$+3.2 \times 10^{-19}$ C	-1.6×10^{-19} C	Zero
Velocity	1.4×10^{7} to 2.2×10^{7} m/s	1% to 99% of the velocity of light	3×10^{8} C
Rest mass	6.6×10^{-27} kg	9.1×10^{-31} kg	Zero

Electron capture

There are a few nuclides in which N/Z is too small for stability but β^{+} emission is not energitically possible. Such nuclides can capture an orbital electron (usually in the K- shell) and a proton in the nucleus can combine to form a neutron and a neutrino. The neutron remains in the nucleus and the neutrino is emitted.

$$_{1}H^{1} + _{-1}e^{0} \longrightarrow _{0}n^{1} + \nu + Q$$
(proton)

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

where $Q = [m(_ZX^A) - m(_{Z-1}Y^A)]c^2$

nuclear mass

(i) After an electron capture, a vacancy is created in the atomic shell and hence X-ray are emitted.

(ii) The electron-capture helps to explain the formation of a neutron star.

γ decay

1) Nucleus has energy levels just like energy levels in atoms
2) The γ decay can be represented as $_ZX^A \rightarrow {}_ZX^A + \gamma$
3) After a α decay or a β-decay, the daughter nucleus is usually in an excited state. The daughter nucleus reactions the ground state by a single transition or sometimes by successive transition by the emitting one or more gamma rays.

Q A radioactive nucleus (initial mass number A and atomic number Z emits 3 α particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be.

$\Rightarrow$ $A - 12$

$Z - 6 - 2$

No. of neutrons $= A - 12 - Z + 6 + 2$

$\Rightarrow A - Z - 4$

Ratio $= \dfrac{A-Z-4}{Z-8}$ Ans

LAW OF RADIOACTIVE DECAY

Radioactivity :- no of nucleons become less and less but always some left

Rate of decay is proportional to the no. of active present nucleons

$$100 \xrightarrow{t_1} 90 \xrightarrow{t_2} 80 \xrightarrow{t_3} 70 \xrightarrow{t_4} 60$$

$$\{t_1 < t_2 < t_3 < t_4\}$$

N_0 $\quad t=0$

$$-\frac{dN}{dt} \propto N$$

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

λ → decay constant

→ depends on nature of nuclei

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

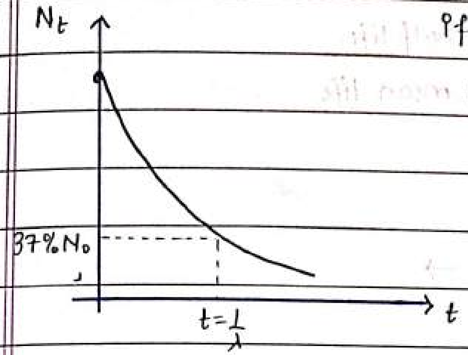
$$[\ln N]_{N_0}^{N_t} = -\lambda t$$

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

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

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

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

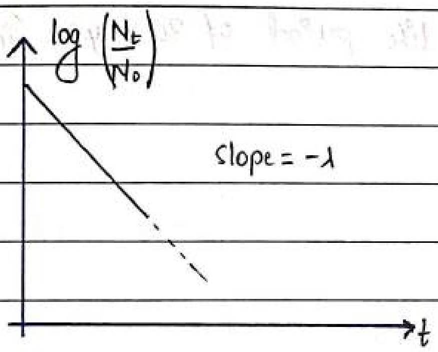


if $t = \frac{1}{\lambda}$

then $N_t = \frac{N_0}{e} = 0.37 N_0$

$= 37\% \ N_0$

$\boxed{\tau = \frac{1}{\lambda}}$ → mean life
average life
↓
time after which conc. becomes $\frac{1}{e}$ times the initial conc.



$$\log_e\left(\frac{N_t}{N_0}\right) = -\lambda t$$

$$y = mx + c$$

Half life

Time after which remaining no. of nucleons becomes half of initial no. of nucleons.

Time after which ~~decayed~~ no. of nucleons becomes double of initial no. of nucleons.

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

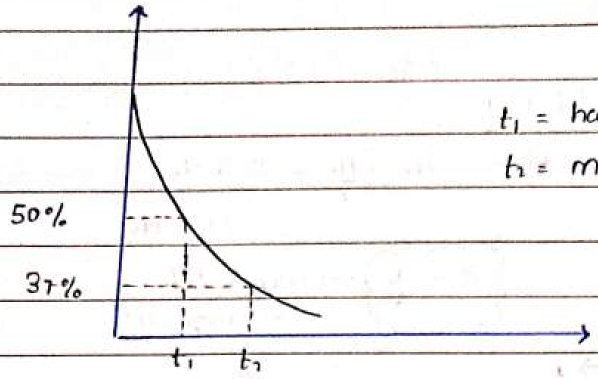
$$\frac{\cancel{N_0}}{2} = \cancel{N_0} e^{-\lambda t}$$

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

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

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

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



t_1 = half life
t_2 = mean life

Q A certain element has half life period of 30 days. Find its average life.

→ $t_{1/2} = 30$ days

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

$\frac{1}{\lambda}$ = mean life = $\frac{30}{\ln 2} = \frac{30}{0.693}$ days $= 43$

Time	No of nuclei at 't' N_t	No. of disintegrate nuclei $N_0 - N_t$	$\frac{N_t}{N_0 - N_t}$ remaining / decayed	$\frac{N_0}{N_0 - N_t}$ Initial / remaining	$\frac{N_0}{N_0 - N_t}$ Initial / decayed
$t=0$	N_0	0	–	–	–
$t = t_{1/2}$	$N_0/2$	$N_0/2$	1:1	2:1	2:1
$t = 2t_{1/2}$	$N_0/4$	$3N_0/4$	1:3	4:1	4:3
$t = 3t_{1/2}$	$N_0/8$	$7N_0/8$	1:7	8:1	8:7
$t = 4t_{1/2}$	$N_0/16$	$15N_0/16$	1:15	16:1	16:15
$t = n\,t_{1/2}$	$N_0/2n$	$N_0 - \frac{N_0}{2^n}$	$\frac{1}{2^n - 1}$	$2^n:1$	$\frac{2^n}{2^n-1}$

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Q. A nuclei decayed from 40% to 85% in 60 hr then find half life of nuclei?

⇒ 40% decayed
↓
60% remaining $\xrightarrow{t_{1/2}}$ 30% $\xrightarrow{t_{1/2}}$ 15% remaining
(85% decayed)

$$2t_{1/2} = 60$$
$$t_{1/2} = 30 \text{ hr}$$

Q. The half life of a radioactive isotope X is 50 years. It decays to another element Y which is stable. The two elements X and Y were formed found to be in the ratio of 1:15 in a sample of a given rock. The age of the rock was estimated to be.

⇒ $4t_{1/2}$ = 50 years ?
$t_{1/2}$ = 50 years
age of rock = $4 \times 50 = 200$ years.

Q. Find the half life period of a radioactive material if its activity drops of $\frac{1}{16}$th of its initial value in 40 years.

⇒ $N_t = \frac{N_0}{16}$ after 4 half life
$$4 \times t_{1/2} = 40$$
$$t_{1/2} = 10 \text{ years.}$$

Can we predict the time of decay?

⇒ No

or can we predict the time between two decay? nor the life time

⇒ No

but we can predict half lif and mean life.

ACTIVITY

The rate of disintegration of sample is called activity

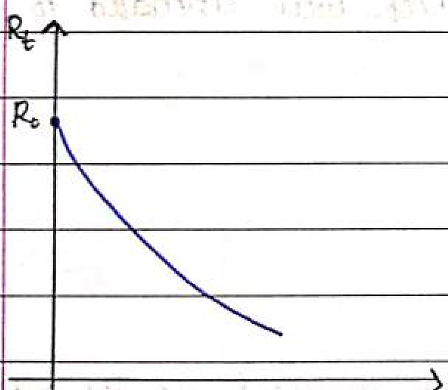
S.I. unit of activity = 1 Becquerel

$1\ Bq = 1\ decay/s$

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

1 Rutherfort $= 10^6\ Bq$

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



activity $R_t = \lambda N_t$ → MR Ratta.

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

$R_t = R_0 e^{-\lambda t}$

$R_0 = \lambda N_0$

R_0: initial activity

N_0: initial no of nucleon

half life is the time after which activity becomes half.

Q The radioactivity of a sample is R_1 at a time T_1 and R_2 at a time T_2. If the half life of the specimen is T, the numbers of atoms that have disintegrated in the time $(T_2 - T_1)$ is proportional to.

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a) $(R_1T_1 - R_2T_2)$ (b) $(R_1 - R_2)$
c) $(R_1-R_2)/T$ (d) $(R_1-R_2)T$

⇒ $R_1 = \lambda N_1$

$R_2 = \lambda N_2$

$N_1 - N_2 = \frac{R_1}{\lambda} - \frac{R_2}{\lambda_2} = \frac{(R_1-R_2)}{\lambda} = \frac{(R_1-R_2)T}{\ln 2}$ Ans

Q The count rate of a Geiger Muller counter for the radiation of the a radioactive material of half life 30 minutes decreases to 5 second^{-1} after 2 hours. The initial count rate was.

⇒ $R_t = \frac{1}{2}$ hour $\qquad \frac{\ln 2}{\lambda} = t_{1/2} = \frac{1}{2}$

$R_t = R_0 e^{-\lambda t}$ $\qquad \lambda = 2\ln 2$

$\ln \frac{R_0}{R_t} = \lambda t$

$\ln \frac{R_0}{5} = \lambda \times 2$ $\qquad \frac{R_0}{5} = 16$

$\ln \frac{R_0}{5} = 4 \ln 2$ $\qquad R_0 = 80$ second^{-1}

$\ln \frac{R_0}{5} = \ln 16$

By concept

$5 \xrightarrow{-30\,min} 10 \xrightarrow{-30\,min} 20 \xrightarrow{-30\,min} 40 \xrightarrow{-30\,min} 80$ ✓

$4 \times 30 = 120$ min $= 2$ hour

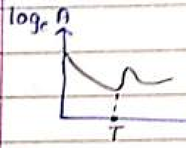
Q ^{40}K isotope of potassium has a half life of 1.37×10^9 years and decays to an isotope of argon which is stable. In a particular sample of moon rock, the ratio of potassium atoms to argon atoms was found to be 1:7. The age of rock, assuming that originally there was no argon present, is.

⇒ $1/2^n - 1 = 1:7$

$n = 3$

$t = 3 \times t_{1/2} = 4.11 \times 10^9$ years.

Q At time $t=0$ some radioactive gas is injected into a sealed vessel. At time T some more of the gas is injected into the vessel. Which one of the following graphs best represents the logarithm of the activity A of the gas with time t?

1)


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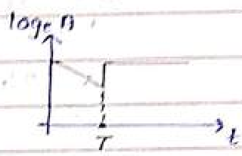
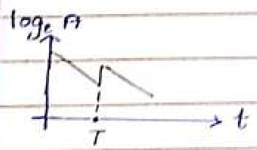
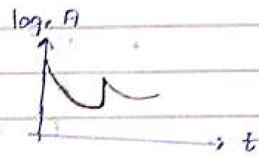


3)


(d)


Q The count rate of a radioactive source at $t=0$ was 1600 count/s and at $t = 8$ s, it was 100 count/s. The count rate (in counts) at $t = 6$ s was

Ans $1600 \xrightarrow[t_{1/2}]{} 800 \xrightarrow[t_{1/2}]{} 400 \xrightarrow[t_{1/2}]{} 200 \xrightarrow[t_{1/2}]{} 100$

$4t_{1/2} = 8$

$t_{1/2} = 2$ sec

After 6 sec

$1600 \xrightarrow[t_{1/2}]{} 800 \longrightarrow 400 \longrightarrow 200$ Ans

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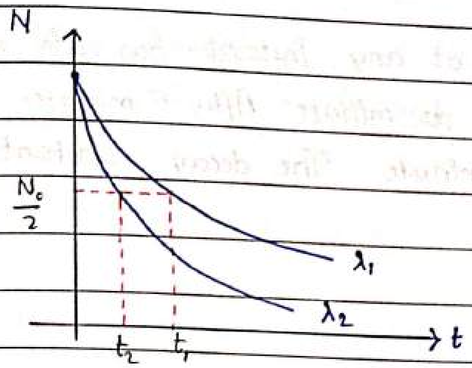
Q



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

$$t_1 > t_2 \therefore \lambda_2 > \lambda_1$$

Q Ten percent of a radioactive sample has decayed in 1 day. After 2 days, the decayed percentage of nuclei will be.

$\Rightarrow$ $100 \xrightarrow{1\ day} 90 \xrightarrow{2^{nd}\ day} 81$

-19 $\therefore$ 19 % has been decayed

Q N atoms of a radioactive element emits n number of α particle per second. Mean life of the element in seconds, is.

1) $\frac{n}{N}$ (b) $\frac{N}{n}$

c) $0.693\frac{N}{n}$ (4) $0.693\frac{n}{N}$

Ans
$$\frac{dN}{dt} = n = \lambda N$$

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

$$\frac{1}{\lambda} = \tau = \frac{N}{n}$$

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Q A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute After 5 minute, the rate is 1250 disintegrations per minute The decay constant (per minute) is.

a) $0.8 \ln 2$ (b) $0.4 \ln 2$
c) $0.2 \ln 2$ (d) $0.1 \ln 2$

Ans $5000 \xrightarrow[t_{1/2}]{} 2500 \xrightarrow[t_{1/2}]{} 1250$

$$2t_{1/2} = 5$$

$$t_{1/2} = 2.5 \text{ minute}$$

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

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

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{\frac{5}{2}} = 0.4 \ln 2$$

Q Two radioactive nuclei P and Q in a given sample decay into a stable nucleus R. At time t=0, number of P species are $4N_0$ and that of Q are N_0. Half life of P (for conversion to R) is 1 minute whereas that of Q is 2 minutes. Initially there are no nuclei of R present in the sample when no. of nuclei of P and Q are equal the no. of nuclei of R present in the sample would be.

a) $5N_0/2$ (b) $2N_0$
c) $3N_0$ (d) $9N_0/2$

Ans $P\ (4N_0) \xrightarrow{1\text{min}} 2N_0 \xrightarrow{1\text{min}} N_0 \xrightarrow{1\text{min}} \frac{N_0}{2} \xrightarrow{1\text{min}} \frac{N_0}{4}$

$Q\ (N_0) \xrightarrow{2\text{min}} \frac{N_0}{2} \xrightarrow{2\text{min}} \frac{N_0}{4}$

Total no. of R nuclei

$$\Rightarrow \left(4N_0 - \frac{N_0}{4}\right) + \left(N_0 - \frac{N_0}{4}\right)$$

$$= \frac{15N_0}{4} + \frac{3N_0}{4} = \frac{18N_0}{4} = \frac{9N_0}{2}$$

Q Half lives of two radioactive substances A and B are respectively 20 minutes and 40 minutes. Initially the samples of A and B have equal number of nuclei. After 80 minutes the ratio of remaining numbers of A and B nuclei is.

$\Rightarrow$ $A \Rightarrow N_0 \longrightarrow \frac{N_0}{2} \longrightarrow \frac{N_0}{4} \longrightarrow \frac{N_0}{8} \rightarrow \frac{N_0}{16}$

$B \Rightarrow N_0 \longrightarrow \frac{N_0}{2} \rightarrow \frac{N_0}{4}$

$$\text{Ratio} = \frac{\frac{\cancel{N_0}}{\cancel{16}\,4}}{\frac{\cancel{N_0}}{\cancel{4}}} = \boxed{1:4}$$

Q The sample of a radioactive substance has 10^6 nuclei. Its half life is 20s. The number of nuclei that will be left after 10s is nearly

$\Rightarrow$ $$N_t = \frac{N_0}{2^n}$$

here $n = 1/2$

$$\therefore N_t = \frac{N_0}{\sqrt{2}} = \frac{10^6}{\sqrt{2}} = 7\times10^5 \text{ } \underline{\text{Ans}}$$

Q Two radioactive sample A and B have decay constant 5λ and λ respectively. At $t=0$ they have the same number of nuclei. The ratio of no. of nuclei of A to those of B will be $(1/e)^2$ after a time interval.

Shivalal

a) $4/\lambda$ (b) $2/\lambda$

(c) $1/2\lambda$ (d) $1/4\lambda$

Ans
$$\frac{N_A = N_0 e^{-5\lambda t}}{N_B = N_0 e^{-\lambda t}} = \left(\frac{1}{e}\right)^2$$

$$\frac{1}{e^{4\lambda t}} = \left(\frac{1}{e}\right)^2$$

$$\frac{1}{e} = \frac{1}{e^{2\lambda t}} \qquad 2\lambda t = 1$$

$$t = \frac{1}{2\lambda} \text{ Ans}$$

Q Radioactive nuclei P and Q disintegrate into R with half lives 1 month and 2 months respectively. At time $t=0$, number of nuclei of each P and Q is x. Time at which rate of disintegration of P and Q are equal, number of nuclei of R is.

a) x (b) $1.25x$

c) $1.5x$ (d) $1.75x$

Ans
$$R_P = R_Q$$

$$\lambda_P N_P = \lambda_Q N_Q$$

$$\frac{\cancel{\ln 2}}{1\,\cancel{\text{month}}} N_P = \frac{\cancel{\ln 2}}{2\,\cancel{\text{month}}} N_Q$$

$$2N_P = N_Q$$

Now $P(x) \xrightarrow{1\text{ month}} \frac{x}{2} \xrightarrow{1\text{ month}} \frac{x}{4}$

$Q(x) \xrightarrow{2\text{ month}} \frac{x}{2}$ $\qquad \frac{x}{2} = 2 \times \frac{x}{4}$

$$\therefore R = \frac{3x}{4} + \frac{x}{2} = 1.25x \text{ Ans}$$

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Shivalal

Q After a lapse of time, fraction of radioactive polonium undecayed is found to be 12.5% of the initial quantity. What is the fraction duration of this time lapse, if half life of polonium is 139 days?

Ans $3 \times 139 = 417$ days

Q The half life of radon is 3.8 days. After how much many days $\frac{19}{20}$ of the sample will decay?

$\Rightarrow$ $N_{remaining} = \frac{N_0}{20}$

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

$\ln \frac{N_0}{N_t} = \lambda t$

$\ln 20 = \frac{\ln 2}{3.8} t$

$t = \frac{\ln 20}{\ln 2} \times 3.8$ Ans

OR By Approximation

After 4 half life $N_t = \frac{N_0}{16}$

After 5 half life $N_t = \frac{N_0}{32}$

$\therefore 4 t_{1/2} < t < 5 t_{1/2}$ **Ans**

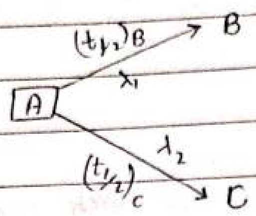
Q A radioactive element reduces to 25% of its initial value in 1000 years. What is $t_{1/2}$

Ans $100 \longrightarrow 50 \longrightarrow 25$

$2t_{1/2} = 1000$

$t_{1/2} = 500$ years.

PARALLEL DISINTEGRATION



$$\boxed{\lambda_{eq} = \lambda_1 + \lambda_2}$$

$$\frac{\cancel{\ln 2}}{(t_{1/2})_{eq}} = \frac{\cancel{\ln 2}}{(t_{1/2})_1} + \frac{\cancel{\ln 2}}{(t_{1/2})_2}$$

$$\boxed{\frac{1}{(t_{1/2})_{eq}} = \frac{1}{(t_{1/2})_1} + \frac{1}{(t_{1/2})_2}}$$

Q Half lives for α and β emission of a radioactive material are 16 years and 48 years respectively. When material decays giving α and β emission simultaneously then time in which $3/4$th of the material decays is.

ANS $t_{eq} = \frac{16 \times 48}{64} \Rightarrow 12$ years

$$N_0 \longrightarrow \frac{N_0}{2} \longrightarrow \frac{N_0}{4}$$

$$\Rightarrow 2\, t_{1/2} \Rightarrow 24 \text{ years}$$

Q A freshly prepared radioactive source of half life 2h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is.

a) 6h (b) 12 h

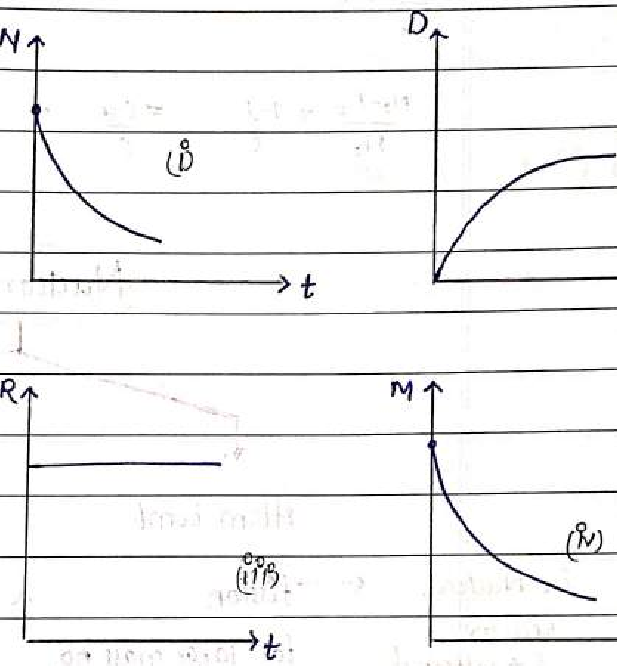
c) 24 h (d) 128 h

Ans $64 \longrightarrow 32 \longrightarrow 16 \longrightarrow 8 \longrightarrow 4 \longrightarrow 2 \longrightarrow 1$

$$6t_{1/2} = 6 \times 2 = 12\ h$$

Q In a radioactive decay let N be the number of residual active nuclei, D the number of daughter nuclei, R the rate of decay and M the mass of active sample at any time t. Below are shown four curves.
The correct ones are

(i) (i), (ii) and (iv)
(ii) (ii), (iii) and (iv)
(iii) (iii), (iv) and (i)
(iv) All of these



Q A sample of radioactive element has a mass of 10 gm at an instant t=0, The approximate mass of this element in the sample after two mean lives.

a) 2.50 gm (b) 1.35 gm
c) 6.30 gm (d) 3.70 gm

Ans

$$t_{1/2} = \frac{\ln 2}{\lambda} \qquad N_t = N_0 e^{-\lambda t}$$

$$N_t = 10\, e^{-\frac{\lambda 2}{\lambda}}$$

$$2 \times \frac{1}{\lambda} = \frac{t_{1/2}}{\ln 2} \times 2 \qquad N_t = \frac{10}{e^2} = 1.35\,gm$$

Q During mean life of a radioactive element, the fraction that disintegrates is.

a) e ~~(b)~~ $\frac{e-1}{e}$

c) $\frac{1}{e}$ (d) $\frac{e}{e-1}$

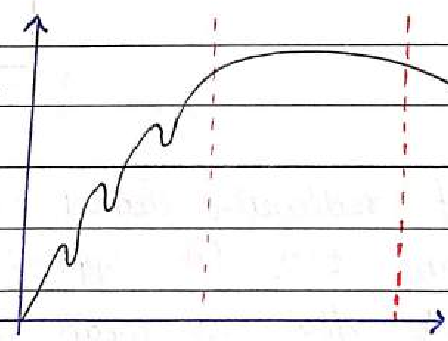
Ans $N_t = N_0 e^{-\lambda t}$

$\frac{N_t}{N_0} = e^{-1}$

$\frac{N_0 - N_t}{N_0} = 1 - \frac{1}{e} = \frac{e-1}{e}$

Nuclear bomb

Atom bomb	Hydrogen bomb
fission (in Nuclear reactor, Q → released)	fusion (in Sun)
for large mass no.	for a small mass no.
eg ⇒ α decay	Q → released
energy released	Q = 0.42 MeV per fusion
⇒ E_{avg} in one fission = 200 MeV	At high temp = 3×10^9 K
	uncontrolled chain Rxn



Nuclear fission

Nuclear fission is a nuclear reaction in which a heavy nuclei breaks into two or more than two daughter nuclei

For nuclear stability.

Spontaneous fission ↓ eg → α decay

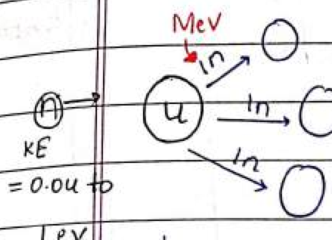
Induced fission.

$${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{236} \longrightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89}$$

$Q = 200$ MeV per fission $\quad 3n$

thermal neutron (n)

KE = 0.04 ev to 1eV



highly energetic electron of the order MeV do not cause nuclear fission.

- $n + {}_{92}U^{235} \longrightarrow {}_{51}Sb^{133} + {}_{41}Nb^{99} + 4\,{}_0n^1 + Q$
- $n + {}_{92}U^{235} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + Q$

In fission daughter nuclei is not fixed

The energy released in single fission = 200 MeV

2.5 neutron Avg released in per fission.

$${}_{92}U^{238} + {}_0n^1 \longrightarrow {}_{92}U^{239} \xrightarrow{-2\beta} {}_{94}Pu^{239}$$

NUCLEAR REACTOR (fission reaction)

Controlled chain Reaction [Critical size K=1]

not freely available (∴ made in fast breeder reactor)

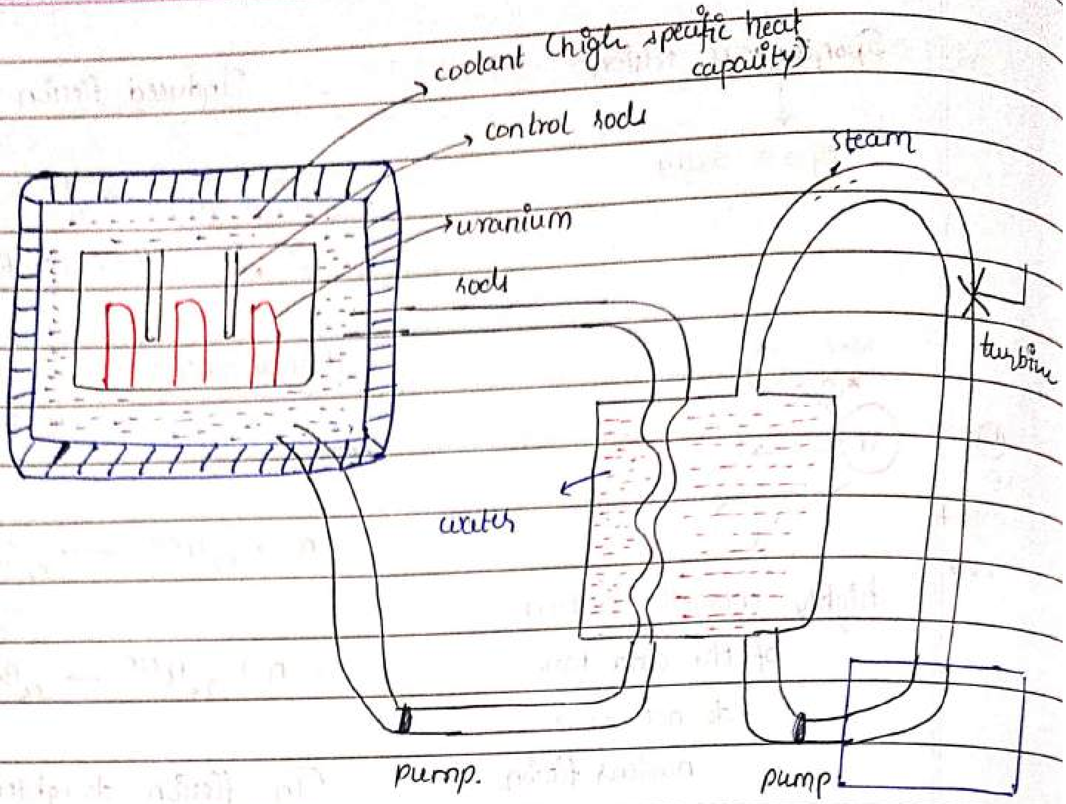
Fuel = ${}_{92}U^{235}$, $\boxed{Pu^{239}}$ → But fuel as it has smaller critical size than U^{235}

→ Avg 2.5 neutron per fission produced

→ It use heavy water (D_2O) and graphite as a moderator to slow down neutron.

→ Control Rods ⇒ ~~Thorium~~, cadmium
B rod

Coolant ⇒ H_2O



Q Heavy water instead of ordinary water is used as a moderator in nuclear reactor because ordinary water.

⇒ Absorb neutrons

Power of nuclear Reactor

$P = \frac{nE}{t}$

$E \Rightarrow$ Energy of one fission

$n \Rightarrow$ no. of fission

$P \Rightarrow$ total Power

$E = 200$ MeV (if not given)

$\frac{n}{t} = \frac{P}{E}$

↓

fission per sec

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Q The power obtained in a reactor using U^{235} disintegration is 1000 kW. The mass decay of U^{235} per hour is

Ans $P = \frac{mc^2}{t}$ $\frac{Pt}{c^2} = m \rightarrow \frac{1000\times10^3\times60\times60}{9\times10^{16}} = \frac{36^4}{9}\times10^{-8}$ kg
$= 4\times10^{-5}$ g
$= 40\ \mu g$ Ans

Q In each fission of $_{92}U^{235}$ energy of 200 MeV is released. How many acts of fission must occur per second to produce a power of 1 kW?

⇒ $\boxed{P = \frac{nE}{t}}$ $\frac{10^3\times1\times10^{19}}{200\times10^6\times1.6} \Rightarrow \frac{10^{14}}{3.2} = \frac{\overset{0.31}{\cancel{10}}}{\cancel{32}}\times10^{14} = 3.1\times10^{13}$ Ans

Q In any fission process the ratio $\frac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is

⇒ less than 1 Ans

Q A neutron strikes a $_{92}U^{235}$ nucleus and as a result $_{36}Kr^{93}$ and $_{56}Ba^{140}$ are produced with

a) α particle (b) 1-neutron
c) 3 neutrons (d) 2-β particle

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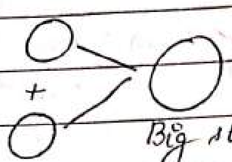
Nuclear fusion

eg (H) → fusion

Condition

a) High temperature

b) High pressure

Small nucleus +  + Energy

Big stable nucleus

$$_1H^1 + {}_1H^1 + {}_1H^1 + {}_1H^1 \longrightarrow {}_2He^4 + 2\,{}_{+1}\beta^0 + 2\nu + 26\ MeV$$

Energy per nucleon in fission $= \frac{200}{235} = 0.85\ MeV$

fusion $\frac{26}{4} = 6.5\ MeV$

The necessary requirements for a modern reactor are given below.

⟨1⟩ Fuel

Usually U^{235} or Pu^{239} is used as the fuel in a nuclear reactor. We know that natural uranium contains only 0.7% of uranium. The remaining 99.3% being U^{238} which is not fissionable by thermal neutrons. Hence, enriched uranium in which U^{235} is increased from 0.7% to about 3% is used as the fuel in the reactor

⟨2⟩ Moderator

The neutrons produced by fission are fast with kinetic energies of the order of 2 MeV. But, fission is induced most effectively by thermal neutrons with kinetic energies of about 0.04 eV. The substance used to slow down the fast neutrons to thermal neutrons is called moderator. A moderator should have the following properties.

(a) Low molecular weight
(b) It should not absorb neutron
(c) It should undergo elastic collision with neutrons and reduce their speeds.

<3> Control rods Coolant

The energy released inside the reactor in the form of heat is removed by coolant. For this purpose air, ice cold water, molten sodium or CO_2 is circulated around the reactor core area which withdraws the heat produced in the core. This heat is utilised for producing steam which is then used to drive turbines for generating electricity.

4) Control rods

The rate of reaction is controlled by inserting or withdrawing control rods made of elements cadmium or boron whose nuclei absorb neutrons without undergoing any additional reaction. When control rods are pushed into the reactor, the fission decreases and when they are pulled out the fission grows.

NUCLEAR ~~FISSION~~ FUSSION

Process in which two or more than two lighter nuclei combine to form a heavier nucleus.

$$ {}_1H^1 + {}_1H^1 \longrightarrow {}_1H^2 + e^+ + Q $$

Temp = 10^7 to 10^9 K 0.42 MeV

$_1H^1 + {_1H^1} \longrightarrow {_1H^2} + e^+ + Q$

$\boxed{+e} \rightarrow v \qquad v \leftarrow \boxed{+e}$

$|\leftarrow\rightarrow|$

r = distance of closest approach $= 10^{-15}$ m

thermal energy $= \frac{3}{2} K_B T = U_B = 400 eV$

U_B: Barrier potential

when $r = 10^{-15}$m

then $U_B = 400 eV$

Temp $= 3 \times 10^9$ K

Q. If 1gm hydrogen is converted into 0.993 gm of helium in a thermonuclear reaction, the energy released in the reaction is.

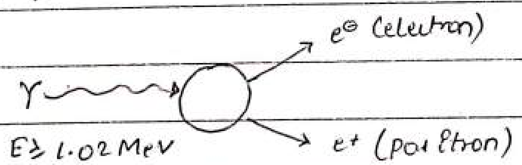
$\Rightarrow$ $E = \Delta m c^2$

$E = 0.07 \text{ gm} \times 10^{-3} \times (3 \times 10^8)^2$

$= 63 \times 10^{10}$ J <u>Ans</u>

Other Nuclear reaction.

1) Pair production $\qquad e^- + e^+ = 1.02$ MeV



$E < 1.02$ MeV $\Rightarrow$ No pair production

2) Pair anneleation