(a) neutrino (b) antineutrino (c) Proton (d) neutron

Q. Carbon dating is best suited for determining the age of fossil, if their age in years is of the order of:
(a) 10^3 (b) 10^4 (c) 10^5 (d) 10^{10}

Note:- The half life of radioactive carbon is 5730 years.

Nuclear Physics

→ Nucleus → discovered by Rutherford by α-scattering experiment.
↳ consist of proton and neutron. Proton and neutron are collectively called nucle
Goldstein J. Chadwick

$_{Z}X^{A}$

Z → atomic no. → no. of proton or electron

A → atomic mass → sum of no. of proton & neutron.

no. of neutron (N) = A − Z

$_{13}Al^{27}$ → no. of proton (Z) = 13, mass no. (A) = 27.
no. of neutron (N) = 27 − 13
= 14

Properties of Nucleus / Nuclear properties

Nuclear charge:- (proton) + (neutron) → No. of protons in a nucleus = Z
proton: +e, neutron: chargeless

∴ charge of nucleus = Ze.
(q)

(ii) Nuclear mass :- Each proton = M_p , Each neutron = M_n

total proton = ZM_p , total neutron = $(A-Z)M_n$

$\therefore$ **Nuclear mass = $ZM_p + (A-Z)M_n$**

(iii) Nuclear size :— Volume $\propto$ A (Mass no.) (size ↑ vol ↑)

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

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

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

R_0 = nuclear radius unit

R_0 = 1.3 Fermi

= 1.3×10^{-15} m.

Nuclear size = 10^{-15} m

Atomic size = 10^{-10} m

Atomic size is 10^5 times Nuclear size

C_{12} & C_{14}

$\frac{R_{12}}{R_{14}} = \left(\frac{12}{14}\right)^{1/3}$

Q. If the mass no. of a nucleus is 216. Find its radius :-

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

$= 1.3 \times (216)^{1/3}$

$= 1.3 \times 6$

$= 7.8$ Fermi

Q. What is the ratio of radius of $_{13}Al^{27}$ and $_{52}Te^{125}$?

$\frac{R_{Al}}{R_{Te}} = \left(\frac{27}{125}\right)^{1/3} = \left(\frac{3}{5}\right)$

$\therefore$ **$R_{Al} : R_{Te} = 3:5$**

(i) Nuclear density :- (ρ_N)

$\rho_N = \frac{\text{Nuclear mass}}{\text{Nuclear volume}} = \frac{ZM_p + (A-Z)M_n}{\frac{4}{3}\pi R^3}$ [$M_p \approx M_n$]

$= \frac{ZM_p + AM_n - ZM_n}{\frac{4}{3}\pi (R_0 A)^{1/3}}$

$\rho_N = \frac{AM_n}{\frac{4}{3}\pi R_0^3 A} = \frac{M_n}{\frac{4}{3}\pi R_0^3}$

$= \frac{1.66 \times 10^{-27}\ kg}{\frac{4}{3} \times 3.14 \times (1.3 \times 10^{-15})^3}$

$\rho_N \approx 2.8 \times 10^{17}\ kg/m^3$

Inside the nucleus.

even a powerful crane can't isolate the nucleons from the nucleus.

Atomic Mass Unit

$$\boxed{1\,amu = \frac{1}{12} \text{ the mass of } C^{12}}$$

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

$E = mc^2$

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

$$\boxed{E = 1.4 \times 10^{-10}\,J}$$

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

$1\,MeV = 1.6 \times 10^{-19} \times 10^6$

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

$\because 1.6 \times 10^{-13}\,J \longrightarrow 1\,MeV$

$1.4 \times 10^{-10}\,J \longrightarrow \frac{1}{1.6 \times 10^{-13}} \times 1.4 \times 10^{-10}\,MeV$

$\approx 931\,MeV$

Conclusion

$$\boxed{1\,amu = 931\,MeV}$$

→ यदि Mass → kg unit मा छ भने, $E = mc^2$ गर ए Energy को unit → Joule हुन्छ

→ यदि Mass → amu मा छ भने, (Δm amu)

$$\boxed{E = \Delta m \times 931\,MeV}$$

Mass defect:-

$M' = Zm_p + (A-Z)m_n \Rightarrow$ Mass of nucleons

$M \rightarrow$ Mass of nucleus

$(M' > M)$

$\Delta m = M' - M$

mass defect

$$\boxed{\Delta m = Zm_p + (A-Z)m_n - M}$$

If Δm is in amu → $\boxed{E = \Delta m \times 931\,MeV}$

Cause of Δm:- To overcome the large repulsive force between protons inside the nucleus (अंदर रोकने पर).

Binding Energy: Energy required to bind the nucleons inside the nucleus.

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

$$\boxed{B.E = \{Z m_p + (A-Z)M_n - M\} c^2}$$

if Δm is in kg.

$\boxed{B.E \rightarrow \text{Joule.}}$

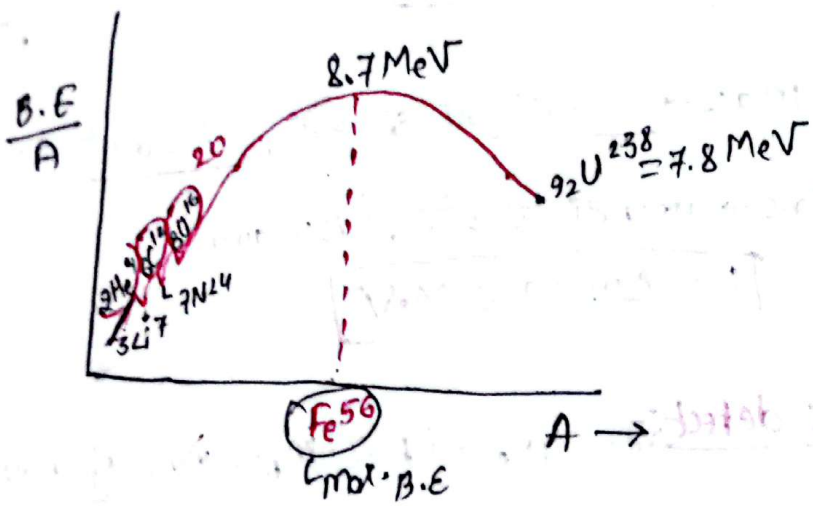
if Δm is in amu

$\boxed{B.E = \Delta m \times 931 \text{ MeV}}$

- Binding energy per nucleon

$$\boxed{B.E \text{ per nucleon} = \frac{B.E}{A}}_{\text{mass no.}}$$

- BE per nucleon curve:- It gives the stability of nucleus.



$_2He^4$ $_6C^{12}$ $_8O^{16}$

↳ even A & even Z

↳ comparatively more stable

- Lighter nuclei are unstable.

(even A & even Z) - extractable

- (After $A_{Z=20}$) → Rises slowly at becomes peak at Fe^{56} ↳ 8.7 MeV

Heavier nuclei
Lighter nuclei
> unstable → moderate

↳ comparatively more stable

Heavier nuclei —Fission→ Moderate

Lighter nuclei —Furion→ Moderate

Q-value of reaction

$x + X \longrightarrow Y + y + Q$ (energy)

- x: bombarding particle
- X: target nucleus
- Y: product nucleus
- y: outgoing product

e.g. $_0n^1 + {}_{92}U^{235} \longrightarrow Ba + K_r + 3\,{}_0n^1 + Q$

$(x+X)$ → Mass of reactant (M_R)

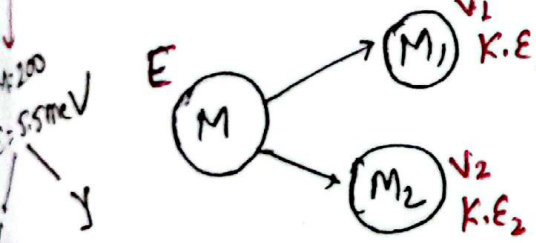
$(y+Y)$ → Mass of product (M_P)

- If $M_R > M_P \Rightarrow$ energy is released $(Q \to +ve)$ → exothermic
- If $M_R < M_P \Rightarrow$ energy is absorbed $(Q \to -ve)$ → endothermic

In every nuclear reaction: Total energy, mass, charge, linear momentum are all conserved.

↳ Most of the energy is converted into K.E.

A nucleus having mass no. 200 disintigrates into a daughter nucleus and α-p
If the Q-value of rxn is 5.5 MeV. Find the kinetic energy of α-particle?



$$K.E_\alpha = \frac{M_y}{M_x + M_y} \cdot Q$$

$$= \frac{196}{200} \times 5.5\,MeV$$

$$\boxed{KE = 5.4\,MeV}$$

$$0 = m_1 v_1 + m_2 v_2$$

$$m_1 v_1 = -m_2 v_2$$

$$\boxed{v_1 = -\frac{m_2}{m_1} v_2}$$

$$E = K.E_1 + K.E_2$$

$$= \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$= \frac{1}{2} m \left(-\frac{m_2}{m_1} v_2\right)^2 + \frac{1}{2} m_2 v_2^2$$

$$= \frac{1}{2} \frac{m_2^2 v_2^2}{m_1} + \frac{1}{2} m_2 v_2^2$$

$$E = \frac{1}{2} m_2 v_2^2 \left(\frac{m_2}{m_1} + 1\right)$$

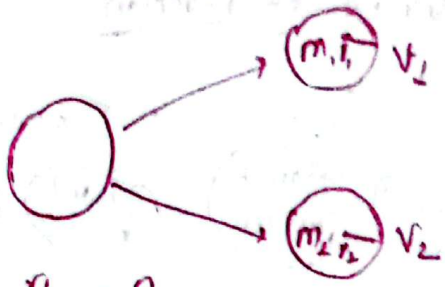
$$E = K.E_2 \left(\frac{m_2 + m_1}{m_1}\right)$$

$$\therefore \boxed{K.E_2 = \left(\frac{m_1}{m_1 + m_2}\right) E}$$

$$K.E = \frac{\text{other mass}}{\text{Total mass}} \times \text{Total energy}$$

Q) The ratio of raduis of two particles formed by rupture of a nucleus is 2:1. What is the ratio of their velocities?

→



$\frac{r_1}{r_2} = 2$

$0 = m_1V_1 + m_2V_2$

$m_1V_1 = -m_2V_2$

$\frac{V_1}{V_2} = \frac{m_2}{m_1}$ (-ve नहीं लिखेंगे)

$\frac{V_1}{V_2} = \frac{\frac{4}{3}\pi r_1^3 \rho}{\frac{4}{3}\pi r_2^3 \rho}$

$\frac{V_1}{V_2} = \left(\frac{r_2}{r_1}\right)^3$

$\frac{V_1}{V_2} = \frac{1}{8}$

$\therefore$ $V_1 : V_2 = 1 : 8$

Q. The binding energy per nucleon of $_3Li^7$ and $_2He^4$ are 5.2 MeV and 7 MeV respectively. What is the energy of proton in the following reaction:-

$$_3Li^7 + p \longrightarrow 2\,_2He^4$$

$\because$ B.E per nucleon $= \frac{B.E}{A}$

B.E = B.E per nucleon $\times$ A

for $_3Li^7$ → B.E = 5.2 × 7 = 36.4 MeV

for $_2He^4$ → B.E = 7 × 4 = 28 MeV

$\therefore$ P = 36.4 − 28

= 7.6 MeV

1. Nuclear ~~Fission~~ Force: strongest force in the nature.

Weakest Force → gravitational force

- → short range force.
- charge independent.

n-n, n-p, p-p

2. $f_1 \rightarrow$ n-n, $f_2 \rightarrow$ n-p, $f_3 \rightarrow$ p-p (n-n, n-p: nuclear force; p-p: electrostatic force)

Which is correct?-

(a) $f_1 = f_2 < f_3$ (b) $f_1 = f_2 > f_3$

(c) $F_1 > F_2 > F_3$ (d) $F_2 = F_3 < F_1$

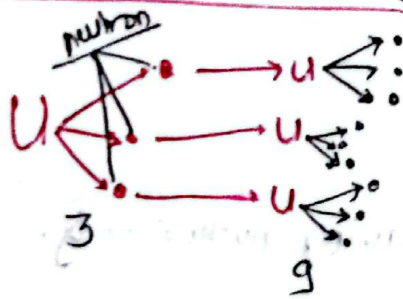
Nuclear fission :- Heavy / Heavier nucleus ($A > 230$) → two or more lighter nuclei along with the release of energy.

$_{92}U^{238}$ – stable → energetic neutron (1 MeV) → fast → so,

$_{92}U^{235}$ – unstable → slow neutron (1 eV) – so, it is best for nuclear fission.

$$_{92}U^{235} + {}_0n^1 \longrightarrow (_{92}U^{236})^* \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1 + Q$$

(* excited; $3\,{}_0n^1$: Sec. neutron)



3 9 27 81

G.P आ neutron को No. बढ्दै गयो जब सम्म uranium sample सकिन्छ।

So, it is uncontrolled chain rxn.

3. Energy equivalent to mass of one electron ?

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

$E = mc^2$

$= 9.1 \times 10^{-31} \times (3 \times 10^8)^2$

$= 9.1 \times 10^{-31} \times 9 \times 10^{16}$

$= 81.9 \times 10^{-15}$ J $= 8.2 \times 10^{-14}$ J

$\Rightarrow \frac{1.6 \times 10^{-13}\ J \rightarrow 1\ MeV}{8.2 \times 10^{-14}\ J \rightarrow \frac{1}{1.6 \times 10^{-13}} \times 8.2 \times 10^{-14}}$

$= 0.5$ MeV

~~# Nuclear~~

- Uncontrolled nuclear chain reaction
  ↓ change गरिन्द
  Controlled chain rxn → also called nuclear reactor.
  - Fuel → U^{235}, U^{236}
    Pu^{239}, Pu^{240} & Pu^{241}
    ↓ best fuel.
  - moderator → slow the energetic sec. neutrons.
    e.g. Heavy water (D_2O) & Graphite
    ↳ best
  - Control rod → absorb the excess neutron.
    e.g. Boron and cadmium rods
  - Coolant → Cool the system.
    e.g. Ordinary water
  - Nuclear reflector → prevents the leakage.

* Energy released per fission of Uranium → 200 MeV

* Multiplication Factor (K)

$$K = \frac{\text{emitted neutron}}{\text{incident neutron}}$$

if $K = 1$ ($e = i$), so, it is called critical state.

$K > 1$ ($e > 1$), So, s super critical state.

Nuclear fusion rxn : lighter nuclei ⟶ Heavier nucleus + Q.

$$1H^2 + 1H^2 \longrightarrow {}_2He^4 + Q.$$

→ $M_R > M_P$ → ($Q = +ve$) → exothermic

→ $M_R < M_P$ → ($Q = -ve$) → endothermic

- Energy obtained in nuclear fusion rxn ~~⇒ 24~~ ≈ 24 MeV

abishek singh