4 · Neutrons physics :

$${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{13}_{6}C^{*} \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

Chadwick introduced a new type of hitherto unknown particle of same mass as the photon. & were electrically neutral

${}^{1}_{0}n$ (${}^{1}_{0}n$) → neutron

$${}^{11}_{5}B + {}^{4}_{2}He \rightarrow {}^{14}_{7}N + {}^{1}_{0}n$$

law of conservation of energy to this rxn,

$$M({}^{11}B) + M({}^{4}He) + E_\alpha = M({}^{14}N) + M_n + E_N + E_n$$

Measuring the energies E_N & E_n Chadwick determined the neutron mass M_n from a knowledge of E_α and using the atomic mass values of the different nuclei.

1.0067 → neutron mass.

Later,

$${}^{2}_{1}H + \gamma \rightarrow {}^{1}_{1}H + {}^{1}_{0}n$$

disintegration of deuteron by γ-rays of known energy (2.62 MeV)

$$P_\gamma = \frac{h\nu}{c} = 1.4 \times 10^{-21}\ kg \cdot m/s$$

Conservation of energy, as applied to the above disintegration process.

$$M({}^{2}H) + E_\gamma = M({}^{1}H) + M_n + E_p + E_n$$

$\frac{1\ amu}{particle} = \frac{1.660540 \times 10^{-27} kg}{mass (kg)} ; \frac{= 1.004}{mass (u)} = \frac{931.1 MeV/c^2}{mass/c^2}$ | $1u = 931.5 MeV$

(28)

$6.022140857 \times 10^{23}$ Avogadro's no.

Here the masses are in energy units.

The measured K.E of the proton produced in the disintegration, $E_p = 0.225$ MeV.

$\frac{1}{6.022140857} = 0.166054$

$$P_p = \sqrt{2 M_p E_p} = (2 \times 1.66 \times 10^{-27} \times 0.225 \times 1.6 \times 10^{-13})^{1/2}$$

$$= 1.09 \times 10^{-20}\ kg\ m/s$$

Hence, $P_\gamma << P_p$

The momentum conservation equation gives

$$P_\gamma = P_p + P_n$$

&

$$M_n = M(^2H) - M(^1H) + E_\gamma - E_p - E_n$$

Approximation, $P_n = P_p$, $E_n = E_p = 0.225$ MeV $= 0.00024150$ u

Also, $E_\gamma = 2.62$ MeV $= 0.002813$ u

$$M_n = 2.014102 - 1.007825 + 0.002813 - 0.0002415 \times 2$$

$$M_n = 1.0086074\ u$$ ⟹ mass of neutron

↳ Radioactive Decay of neutron

$$^1_0n \rightarrow {}^1_1H + \beta^-$$

4. Classification of Neutrons According to Energy

(a) Slow neutrons ($0 < E < 10^3$ eV)
(b) Intermediate neutrons (10^3 eV $< E < 5\times10^5$ eV)
(c) Fast neutrons (0.5 MeV $< E <$ 10 MeV)
(d) Very fast neutron (10 MeV $< E <$ 50 MeV)
(e) Ultra fast neutron ($E >$ 50 MeV)

(a) Slow neutrons:

(i) Cold neutrons: Energy less than ~ 0.002 eV.
They show very high penetrability through crystalline & polycrystalline materials

(ii) Thermal neutrons. low absorption cross-section
achieve thermal equilibrium with the atoms or molecules of the medium

(iii) Epithermal neutrons: high energy neutron achieve thermal equilibrium with molecules in the medium

(iv) Resonance neutrons. very sharp resonances produced in heavier nuclei by these neutrons.

(b) Intermediate neutrons: neutrons mostly suffer elastic scattering

(c) Fast neutrons: Emission of two or more particle become possible, Exp. (n, 2n) (n, pn)
(Product, Rxn, produce)

(d) Ultrafast neutrons. These neutrons are produced in (pn) reactions by very high energy protons accelerated in Ultrafast high energy accelerators

Interaction of Neutrons with matter

Neutral particle follow straight path.

In short neutron collide with nuclei → not with atom. (not interact with e

Neutron interact with nuclei in one of following way

Neutron – nucleus Rxn (cross-section):

- → Scattering
  - elastic (n, n) — σ_e
  - inelastic (n, n') — σ_i
- → Absorption
  - Capture (n, γ) — σ_c
  - fission (n, f) — σ_f
- → transfer
  - transfer reactions (n, 2n) (n, α) (n, p) — σ_{Rx}

~~Cross~~

Cross – section : → determines the probability of the Reaction of will happen in the Rxn.