JEE MAIN

MODERN PHYSICS - PART 5

FORMULAE

NUCLEAR PHYSICS

Now that's how you REVISE

-Mohit Goenka, IIT Kharagpur

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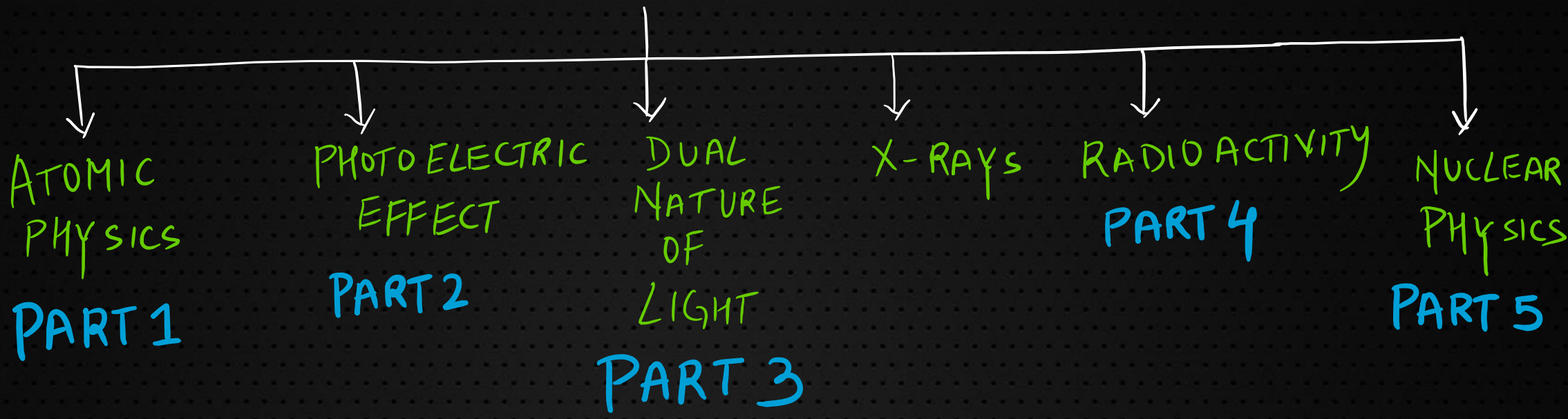
MODERN PHYSICS



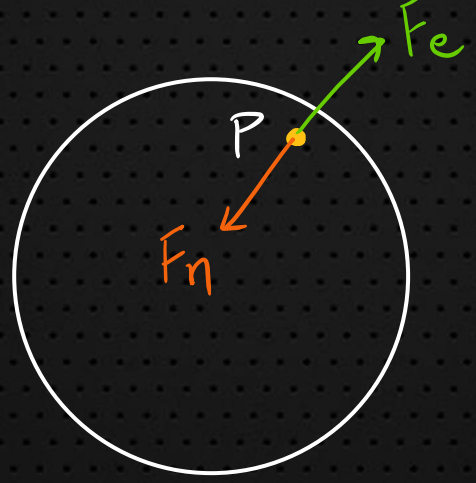
1. HOW TO WRITE A NUCLEAR REACTION

END NUCLEI

$$C + c \longrightarrow D + d$$

- C: Initial nuclei
- c: Attacking Particle
- d: emitting Particle (RADIATION)

$$C(c,d)D$$



2. NUCLEAR FORCE

$^{A}_{Z}X$

Mass no ← A

Atomic no ← Z

Strong attractive short range force.

$$F_{nn} = F_{np} = F_{pp}$$

(i) F_e : repulsive electrostatic force

F_n : net attractive nuclear force

$F_e = F_n \Rightarrow$ Stable Nucleus

3. NUCLEUS SIZE AND STABILITY OF HEAVY NUCLEUS

↳ Size of Nucleus $\propto$ Atomic mass

$\Rightarrow \frac{4}{3}\pi R^3 \propto A \Rightarrow \boxed{R = R_0 A^{1/3}}$

R_0 : fermi-const. $R_0 \sim 10^{-15}$ m

↳ If $R \uparrow \Rightarrow F_n \downarrow$

So, Nucleus gets unstable

$\Rightarrow$ Decay starts

$X \longrightarrow Y +$ Radiation

4. NUCLEAR BINDING ENERGY

the energy required to separate an atomic nucleus completely into its constituent protons and neutrons, or, equivalently, the energy that would be liberated by combining individual protons and neutrons into a single nucleus.

$$Z\,p + (A-Z)\,n \longrightarrow {}^{A}_{Z}X + E_b$$

E_b : BINDING ENERGY

NOTE : When reactants combine to form stable product, THERE IS MASS LOSS called "MASS DEFECT"

$$\boxed{\Delta m = Z m_p + (A-Z) m_n - M_X}$$

and, $E_b = \Delta m c^2$ { Δm if in AMU, 1 AMU $= 1.66 \times 10^{-27}$ kg

OR

$$\boxed{E_b = \Delta m \text{ (in AMU)} \times 931.5 \text{ MeV}}$$

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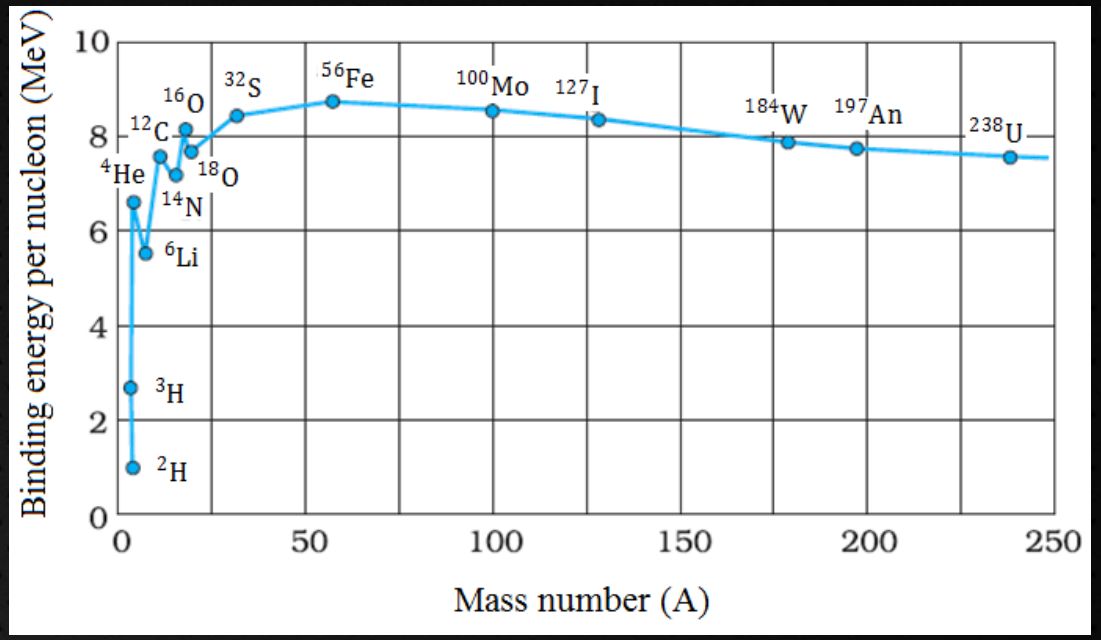
5. BINDING ENERGY PER NUCLEON

↳ $_{Z}^{A}X$ A is no of nucleons

NOTE: E_b is lower for $A<30$ and $A>170$

BE/nucleon $= \frac{E_b}{A}$

↓ tells how stable is a nucleus



6. NUCLEAR FISSION AND FUSION

↳ $A + B \longrightarrow C + \Delta E_1$ (JOINING of nucleus)

↓

$X \longrightarrow Y + z + \Delta E_2$

(splitting)

(i) In both Energy released

(ii) $\Delta E_1 = (m_A + m_B - m_C)c^2$

$\Delta E_2 = (m_X - m_Y - m_Z)c^2$

* NOTE: Energy released (+VE) or even supplied (-VE) is called Q-Value

$Q = \Delta m c^2$

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7. Alpha, BETA AND GAMMA DECAY

(a) α-decay (He Nucleus)

$$ {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha + E \qquad Q = (M_x - M_Y - M_\alpha)c^2 $$

NOTE: THIS energy is released in form of Kinetic energy.

$$ M_Y V_Y = M_\alpha V_\alpha \quad -(i) \qquad Q = \frac{1}{2} M_Y V_Y^2 + \underbrace{\frac{1}{2} M_\alpha V_\alpha^2}_{K_\alpha} \quad -(ii) $$

from (i) and (ii):

$$ K_\alpha = \frac{Q M_Y}{M_\alpha + M_Y} = \boxed{\frac{Q(A-4)}{A}} $$

(b) Beta Decay (e^- or e^+)

e^- → electron, e^+ → positron

ν → neutrino

$\bar{\nu}$ → antineutrino

β^+ Decay

$$p \longrightarrow n + e^+ + \nu$$

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

$$\Delta m = M_X - M_Y - 2m_e$$

β^- Decay

$$n \longrightarrow p + e^- + \bar{\nu}$$

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

$$\Delta m = M_X - M_Y$$

K capture

$$p + e^- \longrightarrow n + \nu$$

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

$$\Delta m = M_X - M_Y$$

(In K capture, e^- is captured from K-shell)

(C) Gamma Decay (EM Radiation)

$$X \longrightarrow Y^* + \alpha \quad , \quad Y^* \longrightarrow Y + \gamma$$

Y^* → Excited state

$$\Rightarrow X \longrightarrow Y + \alpha + \gamma$$

NOTE: It can happen even for β-decay