CLASS 12 PHYSICS — FORMULA SHEET

Chapter 13 : Nuclei (NCERT)

13.1 Nucleus — Composition & Size

Concept	Formula / Detail
Notation	${}^{A}_{Z}X$: A = mass number, Z = atomic number, N = A − Z neutrons
Nuclear radius	$R = R_0 A^{1/3}$; $R_0 = 1.2 \times 10^{-15}$ m (fermi)
Nuclear volume	$V \propto A$ (proportional to mass number)
Nuclear density	Nearly constant (2.3×10^{17} kg/m^3), independent of A
Atomic mass unit (u)	1 u = 1.66×10^{-27} kg = 931.5 MeV/c^2
Isotopes / isobars / isotones	Same Z / same A / same N

13.2 Mass–Energy & Binding Energy

Concept	Formula
Einstein mass–energy	$E = mc^2$; 1 u = 931.5 MeV
Mass defect	$\Delta m = [Z m_p + (A-Z) m_n] - M_{nucleus}$
Binding energy	$BE = \Delta m \times c^2 = \Delta m$ (in u) $\times$ 931.5 MeV
Binding energy per nucleon	$BE/A = BE \div A$ (measure of stability)
Most stable nuclei	Around $A \approx 56$ (iron) ; $BE/A \approx 8.8$ MeV (maximum)
Heavy & light nuclei	Lower BE/A → less stable → undergo fission/fusion

13.3 Radioactivity & Decay Law

Concept	Formula
Radioactive decay law	$N = N_0 e^{(-\lambda t)}$ (λ = decay constant)
Activity	$A = \lambda N = A_0 e^{(-\lambda t)}$; unit becquerel (Bq) or curie (Ci)
Half-life	$T_{1/2} = 0.693 \div \lambda = (\ln 2) \div \lambda$
Mean (average) life	$\tau = 1 \div \lambda = T_{1/2} \div 0.693 = 1.44\, T_{1/2}$
After n half-lives	$N = N_0 \div 2^n$; $n = t \div T_{1/2}$
1 curie	1 Ci = 3.7×10^{10} Bq (decays/sec)

13.4 Types of Radioactive Decay

Decay	Equation & Detail
Alpha (α) decay	${}^{A}_{Z}X \rightarrow {}^{(A-4)}_{(Z-2)}Y + {}^{4}_{2}He$; A↓4, Z↓2
Beta-minus (β⁻) decay	${}^{A}_{Z}X \rightarrow {}^{A}_{(Z+1)}Y + e^- + \bar{\nu}$; neutron → proton
Beta-plus (β⁺) decay	${}^{A}_{Z}X \rightarrow {}^{A}_{(Z-1)}Y + e^+ + \nu$; proton → neutron
Gamma (γ) decay	Excited nucleus → ground state + γ photon ; A & Z unchanged

Decay	Equation & Detail
Penetrating power	$\gamma > \beta > \alpha$
Ionising power	$\alpha > \beta > \gamma$

13.5 Nuclear Fission & Fusion

Concept	Detail
Nuclear fission	Heavy nucleus splits into lighter nuclei + energy (e.g. U-235)
Fission example	${}^{235}_{92}U + n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3n$ + energy
Energy per fission	200 MeV
Chain reaction	Released neutrons trigger further fissions
Nuclear fusion	Light nuclei combine into a heavier one + energy
Fusion example	Hydrogen → helium (powers the Sun)
Why energy is released	Products have higher BE/A → mass converted to energy
Conditions for fusion	Very high temperature & pressure (thermonuclear)

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Nuclear radius	$R = R_0 \times A$ raised to 1/3. Density is the SAME for all nuclei (independent of A).
1 u = 931.5 MeV	Convert mass defect (in u) to energy by multiplying by 931.5 MeV.
Binding energy	$BE = \Delta m \times 931.5$ MeV. Higher BE/A → more stable nucleus.
Most stable	Iron (A about 56) has the highest BE/A, about 8.8 MeV.
Half-life	$T_1/_2 = 0.693/\lambda$; mean life $\tau = 1/\lambda = 1.44\ T_1/_2$.
n half-lives	$N = N_0/2^n$. After 3 half-lives, 1/8 remains.
Penetration vs ionisation	Penetration: $\gamma>\beta>\alpha$. Ionisation: $\alpha>\beta>\gamma$ (exactly reversed).
Fission vs fusion	Both release energy by moving toward higher BE/A (iron peak).