# Nuclei Class 12 Formula Sheet

CBSE Class 12 Physics · NCERT · for boards, NEET and JEE revision

ChapterNotes

## Nucleons, Z and A

$$A = Z + N \cdot \text{notation } {}^{A}_{Z}X \text{ (Z protons, A−Z neutrons)}$$

1 u = 1.66 × $10^{-27}$ kg ≈ 931.5 MeV of energy.

- Protons + neutrons = nucleons; Z = protons, A = total nucleons.
- Neutron count = A – Z (a frequent slip is using A).
- Masses measured in atomic mass unit u, not kilograms.

## Nuclear Radius and Density

$$R = R_0 A^{1/3},\ R_0 = 1.2 \text{ fm} \cdot \rho \approx 2.3 \times 10^{17} \text{ kg/m}^3$$

Radius ratio = cube root of A ratio; volume ratio = A ratio.

- Volume V ∝ $R^3$ ∝ A, so V is directly proportional to mass number.
- Mass ∝ A and volume ∝ A ⇒ density is constant for all nuclei.
- Nuclear matter is ~$10^{14}$ times denser than water.

## Mass Defect & Binding Energy

$$\Delta m = [Z m_p + (A-Z) m_n] - M \cdot E_b = \Delta m \times 931.5 \text{ MeV}$$

Use Δm in u; $E_b$ is energy to break the nucleus into free nucleons.

- Δm is always positive for a bound nucleus (free nucleons – nucleus).
- By E = Δm $c^2$, lost mass appears as binding energy.
- Larger $E_b$ ⇒ more tightly bound, harder to break.

## Binding Energy per Nucleon

$$\bar{E} = E_b / A \cdot \text{peak near } A \approx 56 \text{ (Fe) at} \approx 8.8 \text{ MeV/nucleon}$$

Average ≈ 8 MeV/nucleon; uranium ≈ 7.6 MeV/nucleon.

- Higher $\bar{E}$ = more stable; iron-region nuclei are the most stable.
- Heavy split (fission) and light merge (fusion) both raise $\bar{E}$ → release energy.
- Flat middle ⇒ nuclear force is short-range and saturates (nearest neighbours only).

## Alpha, Beta & Gamma Decay

$$\alpha: {}^{4}_{2}\text{He (Z−2, A−4)} \cdot \beta^-: \text{(Z+1, A same)} \cdot \gamma: \text{(Z, A same)}$$

Penetration: γ > β > α; ionising power is the reverse: α > β > γ.

- α = helium nucleus; $\beta^-$ = neutron → proton + electron + antineutrino.
- γ = high-energy photon from nuclear de-excitation, no Z/A change.
- Balance every decay by conserving both charge Z and mass number A.

## Exponential Decay Law

$$dN/dt = -\lambda N \rightarrow N = N_0 e^{(-\lambda t)}$$

Decay is independent of temperature, pressure or chemistry.

- λ = decay constant = probability per second a nucleus decays.
- Large λ ⇒ fast decay; small λ ⇒ long-lived sample.
- Each decay is governed by probability, not the nucleus's age.

## Half-Life & Mean Life

$$T_{12} = 0.693 / \lambda \cdot \tau = 1 / \lambda \approx 1.44\, T_{12}$$

After n = $t/T_{12}$ half-lives, fraction left = $(1/2)^n$.

- 0.693 ≈ ln 2 ties λ, $T_{12}$ and τ together - find any from one.
- Mean life τ is longer than the half-life, not shorter.
- Fraction remaining = $(1/2)^n$; fraction decayed = 1 – $(1/2)^n$.

## Activity of a Sample

$$A = \lambda N = A_0 e^{(-\lambda t)}$$

SI unit becquerel (Bq) = 1 decay/s; 1 curie (Ci) = 3.7 × $10^{10}$ Bq.

- Activity ∝ N, so it also halves every half-life.
- After 3 half-lives activity drops to 1/8 of the start value.
- Bq is decays per second; curie is the older, much larger unit.

## Nuclear Fission

$$^{235}\text{U} + \text{n} \rightarrow {}^{141}\text{Ba} + {}^{92}\text{Kr} + 3\text{n} + \sim 200 \text{ MeV}$$

Moderator (heavy water/graphite) slows neutrons; control rods absorb them.

- ≈ 200 MeV released per U-235 fission, mostly as fragment kinetic energy.
- Freed neutrons trigger more fissions → self-sustaining chain reaction.
- Slow (thermal) neutrons are captured by U-235 far more readily.

## Nuclear Fusion

$$^{2}\text{H} + {}^{3}\text{H} \rightarrow {}^{4}\text{He} + \text{n} + 17.6 \text{ MeV}$$

Needs ~$10^7$ K to overcome Coulomb repulsion (thermonuclear).

- Per nucleon, fusion releases more energy than fission.
- High temperature lets nuclei beat their mutual electrical repulsion.
- Both fission and fusion release energy: products have higher $\bar{E}$, lower mass.

## Quick revision

- $R = R_0 A^{1/3}$; nuclear density same for all nuclei (~2.3 × $10^{17}$ kg/m³)
- BE = Δm × 931.5 MeV; BE/A peaks at Fe-56 (most stable)
- α: Z–2, A–4; $\beta^-$: Z+1, A same; γ: no change
- $N = N_0 e^{(-\lambda t)}$; $T_{1/2} = 0.693/\lambda$
- Fission: heavy → light + energy (reactors); Fusion: light → heavy + energy (stars)

Full chapter notes with solved examples and practice questions: https://chapternotes.in/cbse/class-12-physics/nuclei-class-12-notes/