Class 12 Physics – Nuclei Study Guide

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1. Theory in Simple Words with Visuals

1.1 What is a Nucleus?

- The nucleus is the **tiny, dense core of an atom**, containing **protons and neutrons**.
- It carries **positive charge** (from protons) and almost all **mass of the atom**.
- Imagine it as a **cherry inside a big watermelon** (the cherry = nucleus, watermelon = atom).

Visual:

```
      Atom
[Electron cloud]  ~ ~ ~
      (Mostly empty)
         •
         •   <-- tiny nucleus (protons + neutrons)
```

1.2 Composition of Nucleus

Particle	Symbol	Charge	Mass (u)	Location
Proton	p^+	+1	1.007	Nucleus
Neutron	n^0	0	1.009	Nucleus
Electron	e^-	-1	0.0005	Outside

- **Mass number (A):** Total number of protons + neutrons
- **Atomic number (Z):** Number of protons
- **Number of neutrons (N):** $N = A - Z$

1.3 Nuclear Forces

- Strong force **binds protons and neutrons together**.
- Short-range but very strong.
- Analogy: **glue holding protons and neutrons** tightly in the nucleus.

1.4 Mass Defect & Binding Energy

- **Mass Defect (Δm):** Nucleus mass < sum of individual nucleons' masses.

- Why? Mass converts into **binding energy** ($E = mc^2$) that holds the nucleus together.

Formula:

$$\text{Binding Energy (BE)} = \Delta m \cdot c^2$$

Example Analogy:

- Like losing a tiny bit of weight when ingredients combine into a cake → energy released as heat (binding energy).

1.5 Nuclear Reactions

- **Radioactive decay:** Nucleus emits particles to become stable.
  - α-decay: emits helium nucleus
  - β-decay: neutron → proton + electron
  - γ-decay: emits gamma radiation
- **Fission:** Splitting of heavy nucleus → energy
- **Fusion:** Combining light nuclei → energy

Visual Table:

Reaction Type	Example	Energy Released?
α-decay	U-238 → Th-234 + α	Yes
β-decay	C-14 → N-14 + β^-	Yes
γ-decay	Co-60 → Co-60 + γ	Yes
Fission	U-235 + n → Ba + Kr + 3n	Huge
Fusion	H + H → He + energy	Huge

1.6 Radioactivity

- Random, spontaneous process.
- Half-life (T½): Time for half the nuclei to decay.

$$N = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

Mnemonic for decay types:
"Alpha Bears Grow Fast" → α, β, γ, fission.

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2. Key Concepts & Formulas

Concept	Formula / Note
Mass number	$A = Z + N$
Binding energy	$BE = \Delta mc^2$
Mass defect	$\Delta m = Zm_p + Nm_n - m_{\text{nucleus}}$
Radioactive decay	$N = N_0 e^{-\lambda t}$
Half-life	$T_{1/2} = \frac{0.693}{\lambda}$
Activity	$A = \lambda N$
Energy-mass	$E = mc^2$
Fission energy	~200 MeV per U-235 nucleus

Mnemonic for BE calculation:
"Nuclear Cake Mass Lost Equals Sweet Energy" → Nucleus → Δm → E=Δmc².

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3. Solved Numerical Problems

3.1 Example 1: Mass Defect

Problem: Mass of He-4 nucleus = 4.0026 u. Mass of proton = 1.0073 u, neutron = 1.0087 u. Find mass defect & BE.

Solution:

1. Total mass of nucleons:
   $2 \times 1.0073 + 2 \times 1.0087 = 4.0320$ u
2. Mass defect:
   $\Delta m = 4.0320 - 4.0026 = 0.0294$ u
3. Convert u → kg: $1u = 1.6605 \times 10^{-27}\text{kg}$
4. BE = Δm c²
   $= 0.0294 \times 1.6605 \times 10^{-27} \times (3 \times 10^8)^2 \approx 4.4 \times 10^{-12}\text{J}$

Tip: Always subtract nucleus mass from sum of nucleons (easy mistake: reversed).

3.2 Example 2: Half-Life

Problem: Half-life of a radioactive isotope = 10 days. Initial sample = 80 g. Find mass after 30 days.

Solution:

1. n half-lives = 30/10 = 3

2. Remaining mass: $80 \times (1/2)^3 = 80/8 = 10$ g

Shortcut: Use powers of 2 → very fast in exams.

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4. Previous Years' Board Questions (2013–2023)

Recurring Patterns:

- Mass defect & binding energy calculations
- Half-life & decay constant numericals
- Fission and fusion questions
- Short definitions: nuclear force, mass number, atomic number

Sample Q:

1. Define binding energy. Find BE for He-4.
2. Half-life of isotope = 5 h, sample = 80 g. Find remaining mass after 15 h.
3. Draw and explain α, β, γ decay.

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5. Quick Revision Notes / Important Points

Visual Memory Map:

```
Nucleus
│
├─ Composition: p + n
├─ Nuclear Force → holds nucleons
├─ Mass Defect → BE
├─ Radioactivity: α, β, γ
├─ Nuclear Reactions: Fission / Fusion
└─ Half-life, Decay constant
```

Key Points:

- Most mass is in nucleus, most volume is empty space
- Mass defect → BE
- Fission = splitting, Fusion = joining
- Half-life formula = t½ = 0.693/λ

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6. Predicted / Likely Questions

- BE & mass defect problems (very frequent)
- Half-life and decay numericals
- Short questions on nuclear reactions
- Diagram: α, β, γ decay paths
- Board loves 1-mark and 2-mark definitions: nuclear force, nucleons, mass number

7. Exam Tips & Tricks

- **Shortcuts:**
  - Powers of 2 for half-life
  - Keep Δm in u, convert at the last step
- **Common mistakes:**
  - Swapping A and Z
  - Forgetting to multiply by c^2
- **Time-saving:**
  - Use tables for decay constants & half-life
  - Draw mini diagrams for decay chains

Flowchart for decay types:

```
Nucleus
│
├─ α → lose 2p+2n → lighter nucleus
├─ β⁻ → n→p + e⁻
├─ β⁺ → p→n + e⁺
└─ γ → energy only, no mass change
```

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8. Visual & Kid-Friendly Learning Style

- Think of **nucleus as a tiny jam-packed cherry in a watermelon**
- Mass defect → tiny "weight lost in cake mixture"
- Fission → splitting firecracker, Fusion → sun fusion
- Use **colors**: red = protons, blue = neutrons, yellow = electrons

Mental Trick:

- **"Protons make it positive, Neutrons neutral, Electrons orbit happily outside"**