FREE NOTES · NCERT + JEE/NEET LEVEL

Nuclei

Nucleus ki banawat, size aur density, mass defect, binding energy aur uska curve, nuclear force, radioactivity, half-life, fission aur fusion. Graphs aur solved numericals ke saath.

01 Nucleus ki banawat
02 Isotopes, isobars, isotones
03 Nucleus ka size & density
04 Mass-energy & mass defect
05 Binding energy per nucleon curve
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01 Nucleus ki banawat

Nucleus me **protons** (Z) aur **neutrons** (N), dono ko milake **nucleons**. Mass number A = Z + N. Likhte hain ${}^{A}_{Z}X$, jaise ${}^{238}_{92}U$.

$1\ \text{u (atomic mass unit)} = 1.66 \times 10^{-27}\ \text{kg} = 931.5\ \text{MeV/c}^2$

$m_p = 1.00728\ \text{u},\ m_n = 1.00866\ \text{u}$

Neutron ko Chadwick ne 1932 me khoja (beryllium pe alpha maarke).

02 Isotopes, isobars, isotones

Naam	Kya same	Example
Isotopes	Z (protons)	${}^{1}H$, ${}^{2}H$, ${}^{3}H$; ${}^{12}C$, ${}^{14}C$
Isobars	A (mass number)	${}^{3}H$ aur ${}^{3}He$
Isotones	N (neutrons)	${}^{198}Hg$ aur ${}^{197}Au$ (dono me 118)

Isotopes ki chemistry same (electrons same), physics alag (mass alag).

03 Nucleus ka size & density

$$R = R_0\, A^{(1/3)},\ R_0 \approx 1.2\ \text{fm}$$

1 fm (fermi) = 10^{-15} m. Volume ∝ A.

DENSITY SABKI SAME!

Mass ∝ A aur volume ∝ A ⇒ **nuclear density har nucleus ke liye lagbhag same**: ≈ 2.3 × 10^{17} kg/m³ (paani se 10^{14} guna). Ek chammach nuclear matter ka weight crores ton! (Neutron stars me aisa hota.)

04 Mass-energy & mass defect

$$E = m\, c^2$$

Einstein: mass aur energy ek doosre me badal sakte. 1 u ⇒ 931.5 MeV.

MASS DEFECT

$$\Delta m = [Z\, m_p + (A - Z)\, m_n] - M_{\text{nucleus}}$$

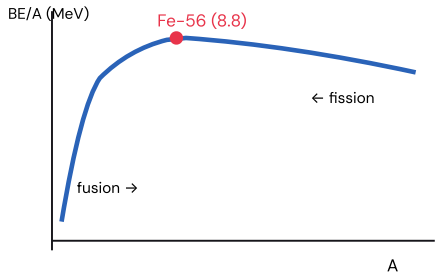
Nucleus ka mass apne alag-alag nucleons ke total se **kam** hota. Ye "gayab" mass hi binding energy hai.

BINDING ENERGY

$$BE = \Delta m \times 931.5\ \text{MeV}\ (\Delta m\ \text{u me})$$

Nucleus ko todke sab nucleons alag karne me lagne wali energy. BE per nucleon = BE/A (stability ka naap).

05 Binding energy per nucleon curve



Beech ke nuclei (A ≈ 30–170) sabse stable

- Peak: **Fe-56** (≈ 8.8 MeV), sabse stable.
- A = 30 se 170 tak lagbhag flat (≈ 8 MeV): nuclear force short range ka saboot.
- Halke nuclei (A < 30) mil ke bade bane ⇒ BE/A badhe ⇒ energy nikle: **fusion**.
- Bhaari nuclei (A > 170) toot ke chhote bane ⇒ energy nikle: **fission**.

06 Nuclear force

- Sabse **strong** force (electric se ~100 guna).
- **Bahut short range** (~2–3 fm). Usse zyada doori pe nahi.
- Charge pe depend nahi: p–p, n–n, p–n sab ke beech same.
- ~0.8 fm se kam doori pe **repulsive** ho jaati (nucleus pichakta nahi).
- Saturation: har nucleon sirf paas wale padosiyon se juda (isliye BE/A lagbhag constant).

07 Radioactivity

Unstable nucleus khud se radiation chhodke stable banne ki koshish (Becquerel ne 1896 me khoja).

	Alpha (α)	Beta (β^-)	Gamma (γ)
Kya hai	He nucleus ^4_2He	Electron (+ antineutrino)	High-energy photon
Charge	+2e	-e	0
A, Z pe asar	$A-4, Z-2$	A same, $Z+1$	Koi badlav nahi
Ionising power	Sabse zyada	Beech	Sabse kam
Penetrating power	Sabse kam (kaagaz rok de)	Beech (aluminium)	Sabse zyada (mota lead)

β^- decay me nucleus ke andar: $n \rightarrow p + e^- + \bar{\nu}$. β^+ me: $p \rightarrow n + e^+ + \nu$ (Z - 1).

08 Decay law & half-life

$$N = N_0\, e^{(-\lambda t)}$$

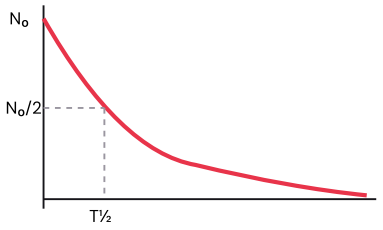
Activity $R = \lambda N = R_0\, e^{(-\lambda t)}$

Half-life $T_{1/2} = \ln 2/\lambda = 0.693/\lambda$

Mean life $\tau = 1/\lambda = 1.44\, T_{1/2}$

n half-lives baad: $N = N_0/2^n$

Activity unit: becquerel (1 decay/s), curie = 3.7×10^{10} Bq.



Exponential decay

YAAD RAKHO

Half-life temperature, pressure, chemical state pe depend nahi karti. Ek akela atom kab tootega, bata nahi sakte (random); sirf bahut saare atoms ke liye law chalta. Carbon dating (C-14, $T_{1/2} \approx 5730$ saal) isi pe.

09 Nuclear fission

Bhaari nucleus neutron lekar do medium nuclei me toot-ta, energy aur 2–3 naye neutrons ke saath.

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

- Naye neutrons aur U toda sakte ⇒ **chain reaction**.
- Uncontrolled ⇒ atom bomb. Controlled ⇒ **nuclear reactor** (bijli).
- Reactor me: **moderator** (bhaari paani, graphite) neutrons dheeme karta; **control rods** (cadmium, boron) extra neutrons sokhte; **coolant** garmi le jaata.
- Multiplication factor K = 1: steady (critical). K > 1: badhta (bomb).

10 Nuclear fusion

Halke nuclei mil ke bhaari nucleus, energy ke saath. Sun aur taaron ki energy isi se: hydrogen → helium.

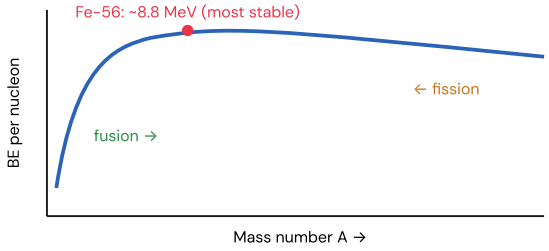
$$^{2}\mathrm{H} + {}^{3}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \mathrm{n} + 17.6\ \mathrm{MeV}$$

Nuclei ko paas laane ke liye repulsion paar karna padta ⇒ **bahut zyada temperature** (~10^7 K) chahiye: **thermonuclear** reaction. Per nucleon fusion me fission se zyada energy, aur radioactive kachra kam.

11 JEE Extra + Tricks

JEE LEVEL

- Nuclear radius $R = R_0 A^{1/3}$ ($R_0 \approx 1.2$ fm) ⇒ har nucleus ki density same (~2.3×10^{17} kg/m³).
- Decay: $N = N_0(½)^{t/T}$; mean life $\tau = 1/\lambda = 1.44\ T_{½}$; activity $A = \lambda N$.
- α decay: A − 4, Z − 2; β^-: Z + 1 (A same); γ: koi badlav nahi. α ki sankhya = ΔA/4; β = 2α − ΔZ.
- Q-value = (reactants ka mass − products ka mass) × 931.5 MeV/u.
- BE per nucleon Fe-56 ke paas peak (~8.8 MeV): halke ka fusion aur bhaari ka fission dono energy dete.



Binding energy per nucleon curve

12 Solved numericals

Q1. ^{27}Al ka radius? (R_0 = 1.2 fm)
R = 1.2 × 27^(1/3) = 1.2 × 3 = 3.6 fm. **Ans: 3.6 fm**

Q2. ^{4}He ka mass 4.0026 u. Binding energy? (m_p = 1.0073, m_n = 1.0087)
Δm = 2(1.0073) + 2(1.0087) − 4.0026 = 4.0320 − 4.0026 = 0.0294 u. BE = 0.0294 × 931.5 ≈ 27.4 MeV, per nucleon ≈ 6.8 MeV. **Ans: ≈ 27.4 MeV**

Q3. ^{238}U → 1 α aur 2 β^- ke baad Z aur A?
α: A 234, Z 90. 2β^-: Z 92, A 234 ⇒ $^{234}_{92}$U (isotope). **Ans: A = 234, Z = 92**

Q4. Half-life 10 din. 40 din baad kitna bacha?
n = 4 ⇒ $N_0/16$ = 6.25%. **Ans: 1/16**

Q5. Half-life 693 s. Decay constant aur mean life?
λ = 0.693/693 = 10^{-3} s^{-1}. τ = 1000 s. **Ans: 10^{-3} s^{-1}, 1000 s**

Q6. 1 g mass poora energy me badle toh kitni energy?
E = 10^{-3} × 9 × 10^{16} = 9 × 10^{13} J. **Ans: 9 × 10^{13} J**

13 Common mistakes

- Nuclear density ko A pe depend maan lena (sabki same).
- β^- decay me A ghata dena (A same, Z + 1).
- Half-life ko temperature pe depend maan lena.
- Mean life aur half-life same samajhna (τ = 1.44 T½).
- Fusion aur fission ki direction curve pe ulti karna.

14 Formula sheet

Radius	$R = 1.2\ A^{(1/3)}\ \text{fm}$
Mass-energy	$E = mc^2,\ 1\ u = 931.5\ \text{MeV}$
Mass defect	$\Delta m = Zm_p + Nm_n - M$
Binding energy	$BE = \Delta m \times 931.5\ \text{MeV}$
Alpha / beta	$A - 4, Z - 2\ /\ Z + 1$
Decay law	$N = N_0 e^{(-\lambda t)},\ R = \lambda N$
Half-life, mean life	$0.693/\lambda,\ 1/\lambda$
After n half-lives	$N_0/2^n$

15 Practice questions

1. A = 8 aur A = 64 nuclei ke radius ka ratio?
2. Kaun sa nucleus sabse stable?
3. Sun ki energy ka source?
4. 75% decay hone me kitni half-lives?

ANSWERS

1) (8/64)^(1/3) = 1 : 2 · 2) Fe-56 · 3) Fusion (H → He) · 4) 2

16 Quick revision: exam se pehle 5 minute

NUCLEUS

- R = 1.2 A^(1/3) fm; density same.
- Isotope Z, isobar A, isotone N same.
- Nuclear force: strong, short range, charge-independent.

ENERGY

- BE = Δm × 931.5 MeV.
- Peak Fe-56, ~8.8 MeV.
- Halka ⇒ fusion; bhaari ⇒ fission.

RADIOACTIVITY

- α: A − 4, Z − 2; β^-: Z + 1.
- Ionising α > β > γ; penetration ulta.
- $T_{1/2} = 0.693/\lambda$; $\tau = 1/\lambda$.

REACTOR

- Moderator: neutron dheema.
- Control rods: neutron sokhna.
- Fusion: ~10^7 K.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.