

Nuclei — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Nuclear Composition and Size

1. Write the relation between the radius of a nucleus and its mass number.
2. Show that the nuclear density is independent of the mass number.
3. State the composition of an atom of ^{235}U .

Mass Defect and Binding Energy

1. Define mass defect and binding energy and write the relation between them.
2. The mass defect of a nucleus is 0.2 u. Find its binding energy.
3. Explain the binding energy per nucleon curve.

Radioactivity and Decay Laws

1. State the laws of radioactive decay.
2. Write the decay equation $N = N_0 e^{(-\lambda t)}$ and explain the terms.
3. Describe the changes in the parent nucleus during alpha and beta decay.

Half-Life and Mean Life

1. Define half-life and derive the relation between half-life and decay constant.
2. Write the relation between mean life and decay constant.
3. The half-life of a sample is 5 years. Find the fraction remaining after 20 years.

Nuclear Fission and Fusion

1. Differentiate between nuclear fission and nuclear fusion.
2. Explain the role of the moderator and control rods in a nuclear reactor.
3. Explain why nuclear fusion is the source of energy in the Sun.

Part B — Integrated problems (multi-topic)

1. The mass defect of a nucleus is 0.1 u. Find its binding energy and the binding energy per nucleon if the mass number is 56.
2. A radioactive sample has a half-life of 20 minutes. Find the time in which $3/4$ of the sample decays and the fraction remaining after 1 hour.
3. The decay constant of a radioactive substance is 0.0693 per year. Find its half-life and mean life.

4. In a nuclear fission reaction, the mass defect is 0.2 u. Find the energy released. How many such fissions are needed to release 1 kWh of energy? (1 kWh = 3.6×10^6 J)
5. The radius of a nucleus with mass number 27 is 3.6 fm. Find the radius of a nucleus with mass number 64.

Answer Key

Nuclear Composition and Size

$r = r_0 A^{1/3}$ with $r_0 \approx 1.2$ fm; nuclear density is constant because mass A and volume A . ^{235}U : 92 protons, 143 neutrons.

Mass Defect and Binding Energy

Δm = mass of nucleons – mass of nucleus; B.E. = $\Delta m c^2 = \Delta m \times 931.5$ MeV. For $\Delta m = 0.2$ u: B.E. = 186.3 MeV. Binding energy per nucleon peaks near $A \approx 56$ (iron).

Radioactivity and Decay Laws

Decay rate = number of undecayed nuclei; $N = N_0 e^{(-\lambda t)}$. Alpha decay: $Z-2$, $A-4$. Beta-minus decay: $Z+1$, A unchanged.

Half-Life and Mean Life

$T_{1/2} = 0.693/\lambda$; mean life $\tau = 1/\lambda$. After 2 half-lives, 1/4 remains.

Nuclear Fission and Fusion

Fission: heavy nucleus splits, releasing energy and neutrons; fusion: light nuclei combine, releasing energy. Moderator slows neutrons; control rods absorb them.

Integrated problems

1: B.E. = $0.1 \times 931.5 = 93.15$ MeV; per nucleon = $93.15/56 \approx 1.66$ MeV. 2: 3/4 decayed after 2 half-lives = 40 min; after 1 h = 3 half-lives, 1/8 remains. 3: $T_{1/2} = 0.693/0.0693 = 10$ years; $\tau = 1/\lambda \approx 14.4$ years. 4: $E = 0.2 \times 931.5 = 186.3$ MeV = 2.98×10^{-11} J; number = $3.6 \times 10^6 / 2.98 \times 10^{-11} \approx 1.2 \times 10^{17}$. 5: $r \propto A^{1/3}$; $r = 3.6 \times (64/27)^{1/3} = 3.6 \times 4/3 = 4.8$ fm.