



what holds a nucleus together, what makes some fall apart, and how fast they do it

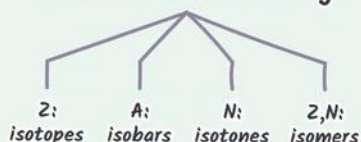
Inside the Nucleus *

- a nucleus is written ${}^A_ZX$: Z is proton count, A is protons+neutrons, $N=A-Z$
- the nucleus is tiny: radius $\sim 10^{-15}$ m vs the atom's $\sim 10^{-10}$ m, a factor of 10^5
- picture the atom as a football stadium: the nucleus is a pea at the centre spot
- nuclear radius: $R=R_0A^{1/3}$ ($R_0=1.33\times 10^{-15}$ m), so nuclear VOLUME is proportional to A
- an electron weighs only $1/1837$ of a proton, so the nucleus holds nearly the whole atomic mass
- packed into that tiny volume, nuclear density runs $\sim 10^{15}$ times ordinary matter

Classifying Nuclides by Composition

- isotopes: SAME Z, different N (and A), e.g. ${}^{22}_{11}\text{Na}$, ${}^{23}_{11}\text{Na}$, ${}^{24}_{11}\text{Na}$
- isobars: SAME A, different Z and N, e.g. ${}^{14}_6\text{C}$ and ${}^{14}_7\text{N}$
- isotones: SAME N, different Z and A, e.g. ${}^{13}_6\text{C}$ and ${}^{14}_7\text{N}$, both $N=7$
- mirror nuclei: isobars whose p and n counts differ by exactly 1, simply swapped
- e.g. ${}^3_1\text{H}$ ($N=2$) and ${}^3_2\text{He}$ ($N=1$)
- nuclear isomers: same Z AND N (same A), differing only in ENERGY state
- the higher-energy one is metastable, marked 'm', e.g. ${}^{60\text{m}}\text{Co}$ next to ${}^{60}\text{Co}$

Nuclides classified by



four different ways to hold one nuclear property fixed while another changes; the name always follows which quantity stays constant

Even-Odd Rule and the N/Z Stability Belt

- of stable nuclides, 165 have even Z and even N ($\sim 85\%$ of the earth's crust)
- only 4 have odd Z AND odd N ($\sim 2\%$): even-even pairing is the most stable arrangement
- protons pair with protons, neutrons with neutrons (no p-n pairing bonus)
- so odd-Z/even-N and even-Z/odd-N counts (55, 50) come out nearly equal
- plotting N against Z for every stable nuclide traces a narrow STABILITY BELT
- nuclides falling outside that belt are radioactive
- for light nuclei (below ${}^{40}_{20}\text{Ca}$) the belt tracks $N=Z$, $N/Z\approx 1$
- for heavier nuclei it curves upward: more neutrons space out the repelling protons

Magic Numbers and Nuclear Potential

- nuclei with 2, 8, 20, 28, 50, 82, 126 p or n are 'magic', unusually stable
- e.g. ${}^{208}_{82}\text{Pb}$ is doubly magic: 82 protons AND 126 neutrons
- protons sit $\sim 10^{-15}$ m apart: coulombic repulsion alone would blow the nucleus apart
- a short-range NUCLEAR force between every nucleon pair (charge-independent) overpowers that repulsion
- this net attraction is the nuclear potential, which binding energy measures the strength of

