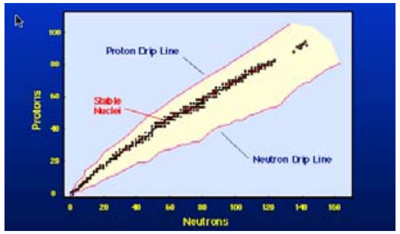
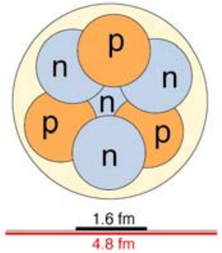
Valley of stability



The stable nuclides are found in the indicated region. It is important to notice that the N/Z ration increases towards higher mass number

What does the nucleus look like ?



Size of a nucleon ca. 1.6 fm
Size of the nucleus $r \approx r_o A^{1/3}$

1 fm (femtometer, fermi) = 10^{-15} m

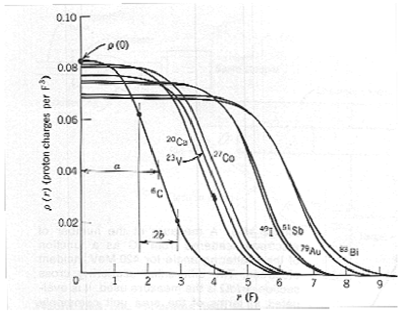
Some important concepts

- Atomic mass:
  - Mass of **neutral** atom with **bound** electrons (M(Z,N))
  - (nucleus mass:mass of "naked" nucleus)
- Binding energy
  - Expressed by mass difference: $BE(Z,N) = ZM(^1H) + NM(^1n) - M(Z,N)$
- Radius
  - $R = r_o A^{1/3}$
- Spin (angular momentum)
  - $I = \sum_A (\ell_i + s_i)$
- Parity
  - + if $\psi(r) = \psi(-r)$
  - - if $\psi(r) = -\psi(-r)$

Mass unit (rep.)

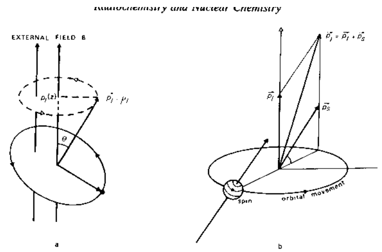
- Mass Unit: 1u = 1/12 mass of the neutral isotope ^{12}C
- 1u = 931.5 MeV
- The mass of a neutron and a proton are both higher than 1u, around 939 MeV.
- Mass excess:
- $\Delta M(Z,A) = M(Z,A) - NM(n) - ZM(^1H)$

Nuclear radii



There are also different proton- and neutron radii (e.g. difference between the isotopes ^{40}Ca and ^{48}Ca)

Nuclear Spin (angular momentum)



The nucleus' total spin is the vector sum of the total spins of all nucleons, i.e. the sum of orbital angular momenta and intrinsic spins

Nuclear properties

- Magnetic moment
  - Bohr-magneton: $\mu_B = eh/4\pi m_e c$
  - Nuclear magneton: $\mu_k = eh/4\pi m_p c$
  - For proton: $\mu_P = 2.79\ \mu_k$
  - For neutron: $\mu_N = -1.91\ \mu_k$
- This shows that the neutron has a charge dispersion, and therefore internal structure. Hence, the neutron is not a "completely elementary" particle.
- Magnetic moment gives information about the states of the nucleons in the nucleus, and is fundamental for NMR:
- $\mu_I = g_I \mu_k I$
  - g_I- gyromagnetic factor

Nuclear properties

- Electric quadrupole moment
  - Gives the differencew from pure spherical shape
  - + Cigar shape
  - - Diskos shape
- Elektric octupole moment
  - Gives "pear shape"
- From high energy physics, special degrees of freedom:
  - Statistics (bosons, fermions)
  - Isospin

Conservation laws

Following degrees of freedom are conserved in nuclear processes:

- Energy
- Momentum
- Angular momentum (spin)
- Charge
- Baryon number (nucleon number)
- Lepton number
- Parity
- Statistics
- Isospin (not for weak interactions)

Conservation laws, examples

Correct disintegration:

$n \Rightarrow p + e^- + \bar{\nu}$

- Primitive model for β-disintegration $n \Rightarrow p + e^-$
- This model breaks the conservation of:
  - Spin (half number → integer impossible)
  - Lepton number
- This lead to the introduction of a "new massless particle", the neutrino
- Later on it was discovered that the neutrino and the antineutrino were different
- (Even later, it was discovered that there are three different classes of neutrinos ν_e, ν_μ and ν_τ)

Concervation laws

Correct disintegration:

$n \Rightarrow p + e^- + \bar{\nu}$

- This model explains the shape of the β-spectrum, the simplistic original model could not explain a continuous spectrum, but predicted a line spectrum, as for α-disintegration.
- β-disintegration is a three particle process