1.1: Basic Concepts

In this chapter we review some notations and basic concepts in Nuclear Physics. The chapter is meant to setup a common language for the rest of the material we will cover as well as rising questions that we will answer later on.

Terminology

A given atom is specified by the number of

- neutrons: N
- protons: Z
- electrons: there are Z electron in neutral atoms

Atoms of the same *element* have same atomic number Z. They are not all equal, however. *Isotopes* of the same element have different # of neutrons N .

Isotopes are denoted by ${}^{A}_{Z}X_{N}$ or more often by

$$\boxed{{}^{A}_{Z}X}$$

where X is the chemical symbol and A = Z + N is the mass number. E.g.: ${}^{235}_{92}U$, ${}^{238}U$ [the Z number is redundant, thus it is often omitted].

When talking of different nuclei we can refer to them as

- Nuclide: atom/nucleus with a specific N and Z.
- Isobar: nuclides with same mass # A ($\neq$ Z, N).
- Isotone: nuclides with same N, $\neq$ Z.
- Isomer: same nuclide (but different energy state).

Units, dimensions and physical constants

Nuclear energies are measured in powers of the unit *Electronvolt*: $1\text{eV} = 1.6 \times 10^{-19}$ J . The electronvolt corresponds to the kinetic energy gained by an electron accelerated through a potential difference of 1 volt. Nuclear energies are usually in the range of MeV (mega-electronvolt, or 10^6 eV).

Nuclear masses are measured in terms of the *atomic mass unit* : 1 amu or $1\text{u} = 1.66 \times 10^{-27}$ kg . One amu is equivalent to 1/12 of the mass of a neutral ground-state atom of ^{12}C. Since electrons are much lighter than protons and neutrons (and protons and neutrons have similar mass), one nucleon has mass of about 1 amu.

Because of the mass-energy equivalence, we will often express masses in terms of energy units. To convert between energy (in MeV) and mass (in amu) the conversion factor is of course the speed of light square (since E = mc^2). In these units we have: $c^2 = 931.502$ MeV/u.

- Proton mass: 938.280MeV/c^2
- Neutron mass: 938.573MeV/c^2
- Electron mass: 0.511MeV/c^2

Note: you can find most of these values in Krane (and online!)

Scales of magnitude for typical lengths are femtometer (1 fm=10^{-15} m) also called Fermi (F) and Angstrom 1° A = 10^{-10} m (for atomic properties) while typical time scales span a very broad range.

Physical constants that we will encounter include the speed of light, c = 299, 792, 458 m s^{-1}, the electron charge, e = 1.602176487 × 10^{-19} C, the Planck constant h = 6.62606896 × 10^{-34} J s and $\hbar$, Avogadro's number N_a = 6.02214179 × 1023 mol^{-1}, the permittivity of vacuum $\epsilon_0 = 8.854187817 \times 10^{-12}$ Fm^{-1} (F=Faraday) and many others. A good reference (online) is NIST: http://physics.nist.gov/cuu/index.html

There you can also find a tool to convert energy in different units: http://physics.nist.gov/cuu/Constants/energy.html

Nuclear Radius

The radius of a nucleus is not well defined, since we cannot describe a nucleus as a rigid sphere with a given radius. However, we can still have a practical definition for the range at which the density of the nucleons inside a nucleus approximate our simple model of a sphere for many experimental situations (e.g. in scattering experiments). A simple formula that links the nucleus radius to the number of nucleons is the *empirical radius formula*:

$$\boxed{R = R_0 A^{1/3}}$$
