Nuclear Physics - Summary - Nuclear Properties

by Dr. Helga Dénes (hdenes@yachaytech.edu.ec)

This summary is based on the book Chapter 3.1-3.3 from Krane, Kenneth: Introductory Nuclear Physics.

1 Nuclear Radius

The nuclear radius is measured in two different ways:

- **mean radius**: where the density falls to half its central value. $R = R_0 A^{1/3}$
- **skin thickness**: the region where the density falls from 90% to 10%

There are two main ways to measure the nuclear radius. The **radius based on the charge distribution**, probed trough the electromagnetic (or Coulomb) force.

- low energy scattering experiments
- K X-ray energy differences (also called isotope shift)
- muonic X-rays: similar to the regular isotope shift, but with captured muons (μ^-) instead of electrons.

Measuring the nuclear density distribution, trough the strong force.

- high energy scattering experiments
- radioactive decay
- π mesonic X-rays: in this case π mesons get captured like and electron by the nucleus. First the π cascades down the "electron" shells to the lowest energy state. During this photons get emitted. Then the π can get absorbed into the nucleus and this disappearance rate can be used to measure the radius.

All methods to measure the nuclear radius give consistent results.

2 Nuclear Mass:

Ways to **measure the nuclear mass**:

- **mass spectrometer:** has the following components: ion beam, velocity selector (with E and B field), momentum selector (with B field). This is a relative measurement also called the **mass doublet method**. Suitable for most isotopes, except fast decaying radioactive materials.
- **nuclear reactions:** Example: nuclear fission (x + X $\rightarrow y + Y$) By measuring the kinetic energy of the reacting particles, we can calculate the mass ratio of the particles, which can be used to measure the mass of one of the particles.

Nuclear abundances: All natural materials are composed of a certain mixture of isotopes.

Isotopes can be separated with the following methods:

- mass spectrometer
- laser isotope separation

Nuclear binding energy: the difference in mass energy between ${}^A_Z X_N$ and its constituents Zp^+ and Nn^0. This can also be expressed as the **mass defect** $\Delta = (m - A)c^2$

Neutron separation energy: the amount of energy that needs to be supplied to a nucleus to remove a neutron. This is the difference in binding energies between ${}^A_Z X_N$ and ${}^{A-1}_{Z} X_{N-1}$. Indicates shell structure of the nucleus.

Proton separation energy: the amount of energy that needs to be supplied to a nucleus to remove a proton. This is the difference in binding energies between ${}^A_Z X_N$ and ${}^{A-1}_{Z-1} X_N$.