Summary nuclear - properties, force, and models

1 Nuclear properties

1.1 Nuclear radius

- mean radius $R = R_0 A^{1/3}$
- skin thickness

1.1.1 Measuring the nuclear radius

1) measuring the charge distribution based on the Coulomb force

- low energy scattering experiments
- K X-ray energies
- muonic X-rays
- coulomb energy difference of mirror nuclei

2) measuring the matter distribution (both p and n) based on the strong force

- high energy scattering experiments
- radioactive decay
- π mesonic X-rays

1.2 Nuclear mass

Measuring the nuclear mass

- mass spectrometer (how does in work, relative measurements, calculations)
- nuclear reactions, nuclear decay

Nuclear abundances - isotopes, isotope separation methods (mass spectrometer, laser isotope separation)

Nuclear Binding energy:

- mass defect (+ calculations)
- neutron separation
- semi empirical mass formula - mass terms + binding energy, the 5 terms of the binding energy

1.3 Nuclear angular momentum and parity

- Total angular momentum (I) is the combination of l and s
- parity: even or odd I^{π} e.g. $0^+, 2^+$ ...

1.4 Nuclear electromagnetic moment

- Q - electric moments
- μ - magnetic moments
- discrepancy of predictions and measurements - p and n are not point like particles, they are composed of quarks, n has internal charge distribution (the quarks are charged particles)

Nuclear pairing force favours coupling of nucleons so that the magnetic moment and the spin magnetic moments of the pairs combine to 0.

Nucleons have excited states (vibrational, rotational and pair breaking excitation), which are related to various properties

2 Nuclear force

Properties of the strong force can be deduced from:

- basic properties of the deuteron
- nucleon-nucleon scattering experiments, p-p, n-n, p-n scattering (cross section, scattering length)

The nucleon-nucleon force can be described by the combination of several potentials:

1. attractive potential
2. spin dependent potential
3. non central term or tensor potential (depends on the direction of the spin)
4. charge symmetry (p-p scattering has the same properties as n-n scattering)
5. nearly charge independent (n-p does not have the same properties as p-p and n-n scattering - explained by the meson exchange model, charged π mesons have a slightly different mass compared to the neutral meson)
6. repulsive at short distances (results from high energy scattering, keeps the nucleons at a certain distance from each other)
7. depends on the relative velocity/momentum of nucleons (in high energy scattering experiments polarization is observed)

The nucleon-nucleon force can be explained by the exchange force model. - Exchange of mesons. Note the strong nuclear force is not the same as the strong force between the quarks inside the nucleons, but it is derived from it.

3 Nuclear models

The **shell model** - analogous to the model of the atom with the electrons occupying different shells. The properties of the nuclei can be explained either by:

- the valance nucleon
- or the unfilled shell

Some agreements with observed properties, but also some discrepancies.

The **liquid drop model** treats the nucleons similar to a drop of liquid. Low excitation modes are explained with

- vibrational modes
- rotational modes (only for deformed high A nuclei)
- and combinations of the rotational, vibrational, and pair breaking excitation modes