Nuclear Physics - Summary - Basic definitions

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This summary is based on the book Chapter 1 from Krane, Kenneth: Introductory Nuclear Physics, and the lecture slides NPP_1.1.

1 Basic definitions

Notation for nuclear species: ${}^{A}_{Z}X_{N}$
where A is the atomic mass number,
Z is the atomic number (number of protons in the nucleus),
N is the number of neutrons in the nucleus.

Isotopes: chemical elements with the same number of Z (protons), but different number of neutrons (N and A are different). They have similar chemical properties to each other, but different physical properties. Examples: ^{12}C, ^{14}C, ^{235}U, ^{238}U.

Isotone: chemical elements with the same number of N (neutrons), but different number of protons (Z and A are different). Examples: ^{2}H, ^{3}He.

Isobar: chemical elements with the same A. They can have different Z nad N. Examples: ^{3}H, ^{3}He; ^{40}S, ^{40}Cl, ^{40}Ar.

Isotopologue: molecules that differ in isotopes. Example: ^{12}CO, ^{18}CO.

Atomic mass unit (u or a.m.u.): basic mass unit in nuclear physics. It is defined that so that the ^{12}C nucleus is exactly 12 u. This makes protons and neutrons approximately, but not exactly 1u in mass.

2 Particles and Forces:

Antiparticles: In particle physics, every type of particle of "ordinary" matter is associated with an antiparticle with the same mass but with opposite physical charges (such as electric charge and colour charge). Some of the quantum numbers of the anti particles are also opposites of the regular particles, such as the electron number. The neutron has an anti particle, however neither the photon (γ) nor the neutral pion (π^0) has a distinct antiparticle. It is a convention to call the electron the particle and the positron its antiparticle.

Particle-antiparticle pairs can annihilate each other, producing photons; since the charges of the particle and antiparticle are opposite, total charge is conserved.

Elementary Particles:
- **Fermions:** particles with half-integer spin.
  - **Leptons**: do not interact trough the strong force. Have spin $\frac{1}{2}$. Examples: e^-, μ^-, τ^-, ν_e, ν_μ, ν_τ
  - **Quarks**: interact trough the strong force. Have spin $\frac{1}{2}$. Examples: u, d, c, s, t, b
- **Bosons:** particles with integer spin. Examples: γ, gluons, W$^+$, W$^-$, Z, Higgs boson

The fermions can be divided into particle generations based on their mass. 1st generation particles are the lightest (e, ν_e, u, d) compared to 2nd generation particles (μ, ν_μ, c, s) and the 3rd generation particles are the heaviest (τ, ν_τ, t, b). Keep in mind that leptons are much lighter than quarks in general and the exact neutrino masses are unknown.

Composit Particles:
- **Hadrons:** bound state of quarks or antiquarks
  - **Baryons:** bound state of 3 quarks or antiquarks. Example: proton, neutron, antiproton

- **Mesons:** bound state of an equal number of quarks and antiquarks. The most typical ones have one quark and an antiquark. Examples: π^0, π^+, π^-

Basic Forces:

- **electromagnetic:** acts between charged particles, the force carrier particle is the photon.
- **strong:** acts between quarks, the force carrier particles are the gluons.
- **weak:** acts between all fermions. The force carrier particles are: W^+, W^-, Z bosons
- **gravity** (negligible for nuclear and particle physics): acts between all particles with mass