Basic concepts of Nucleus

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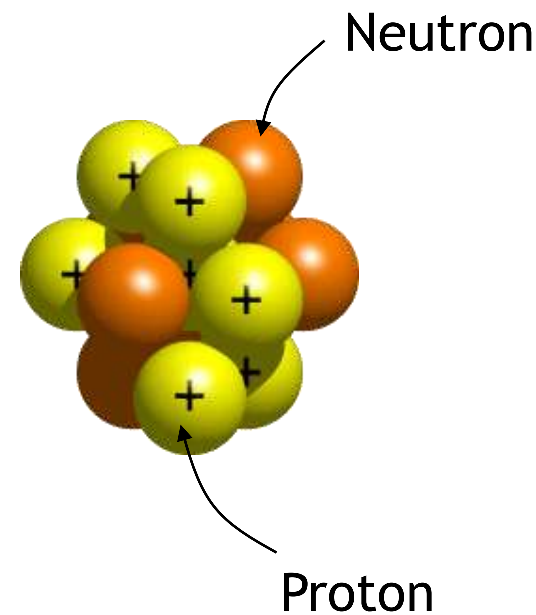
Physics of the Nucleus

- Nucleus consists of protons and neutrons densely combined in a small space (~10^{-14} m)
  - Protons have a positive electrical charge
  - Neutrons have zero electrical charge (are neutral)
- Spacing between these **nucleons** is ~ 10^{-15} m



- Size of electron orbit is $5x10^{-11}$ m
- Nucleus is 5,000 times smaller than the atom!

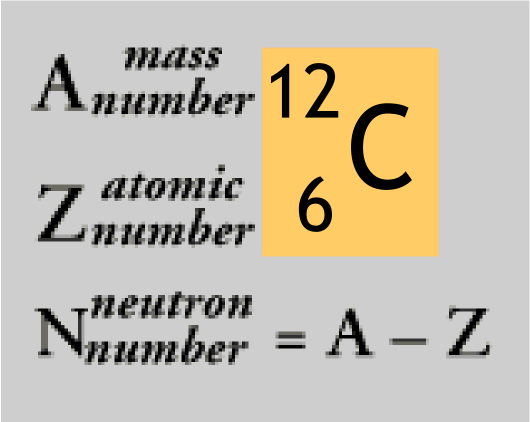
Neutrons and Protons

Neutron: zero charge (neutral)

Proton: positive charge (equal and opposite to electron)

- The number of protons in a nucleus is the same as the number of electrons since the atom has a net zero charge.
- The number of electrons determines which element it is.
  - 1 electron $\rightarrow$ Hydrogen
  - 2 electrons $\rightarrow$ Helium
  - 6 electrons $\rightarrow$ Carbon
- How many neutrons?

Carbon



- Example: carbon
- Carbon has 6 electrons (Z=6), this is what makes it carbon.
- Zero net charge so there are 6 protons in the nucleus.
- Most common form of carbon has 6 neutrons in the nucleus. Called ^{12}C

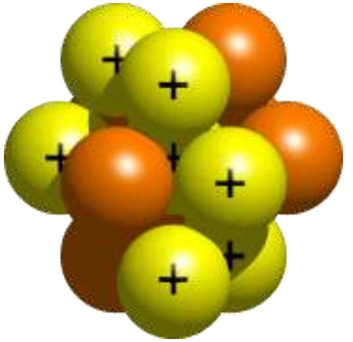
Another form of Carbon has 6 protons, 8 neutrons in the nucleus. This is ^{14}C.

Isotopes

- Both ^{12}C and ^{14}C have same chemical properties.
- This is why they are both called carbon. Same # electrons and same # protons in nucleus.
- But the nuclei are different. They have different number of neutrons. These are called isotopes.
- Difference is most easily seen in the binding energy.
- Nuclei that are bound more tightly are less likely to 'fall apart'.
- In fact ^{14}C is radioactive or unstable.

Nuclear Force

- So what holds the nucleus together?
- Coulomb force? Gravity?
- Coulomb force only acts on charged particles
  - *Repulsive* between protons, and doesn't affect neutrons at all.



- Gravitational force is much too weak. Showed before that gravitational force is much weaker than Coulomb force.

The Strong Nuclear Force

- New force.
- Dramatically stronger than Coulomb force.
- But not noticeable at large distances.
  - I.e. Atoms do not attract each other.
- Must be qualitatively different than Coulomb force.
- How can we characterize this force?
  - Range is on the order of the size of nucleus.
  - Stronger than Coulomb force at short distances.

Estimating the strong force

The Coulomb attraction energy (~10 eV) binds the hydrogen atom together.

Protons in nucleus are 50,000 times closer together than electron and proton in hydrogen atom.

The Coulomb energy is inversely proportional to the separation.

Attractive energy must be larger than the Coulomb repulsion, so nuclear binding energies are greater than.

A. 5000 eV

B. 500,000 eV

C. 5,000,000 eV

A strong nuclear force

- Electron is bound in atom by Coulomb attraction. Strength ~10 eV.
- Protons in nucleus are 50,000 times closer together. Coulomb repulsion ~500,000 eV = 0.5 MeV
- Nuclear force must be much stronger than this.
- Experimentally, the strong nuclear force is ~ 100 times stronger than Coulomb force
- Nucleons are bound in nucleus by ~ 8 MeV / nucleon (8,000,000 eV / nucleon)