The atomic nucleus consists of positively charged protons and neutral neutrons.

\[ A = Z + N \]

\[ r \approx (1.2 \times 10^{-15} \text{ m}) A^{1/3} \]
### Nuclear Stability

⇒ Each proton in the nucleus exerts a repulsive electrical force on every other proton.

⇒ The force between protons in the nucleus can be calculated from Coulomb’s law:

\[
F = \frac{k|q_1 q_2|}{r^2} = \frac{(8.99 \times 10^9 \text{N m}^2/\text{C}^2)(1.60 \times 10^{-19} \text{C})^2}{(1.0 \times 10^{-15} \text{m})^2} = 230 \text{N}
\]

⇒ From \( a = F/m \),

\[
a = \frac{230 \text{N}}{1.67 \times 10^{-27} \text{kg}} = 1.4 \times 10^{29} \text{ m/s}^2
\]

### Nuclear Stability

⇒ If there wasn’t some other (attractive) force, the nucleus would fly apart in an instant!

**strong nuclear force** ⇒ the attractive force that holds the nucleus together

⇒ the strong nuclear force is also responsible for holding together protons and neutrons which are made of quarks

### Nuclear Stability

⇒ there are two important properties of the strong nuclear force:

1) it is a short range force, acting only to distance of about \(10^{-15}\) m

2) it is always attractive and acts with nearly the same strength between protons & protons, protons & neutrons, and neutrons & neutrons

### Nuclear Stability

⇒ The repulsive electric force acts over long ranges so every proton in the nucleus repels every other proton.

⇒ In contrast, a proton or a neutron only attracts its nearest neighbors via the strong force.

⇒ As the number of protons increases, the number of neutrons must increase even more if the nucleus is to be stable.
Nuclear Stability

⇒ As Z increases, eventually (Z = 83) a balance of repulsive and attractive forces cannot be achieved by increasing the number of neutrons.

⇒ All nuclei with more than 83 protons (Z ≥ 84) are unstable and eventually break apart or rearrange their internal structure (decay).

α - Decay

\[ {}_Z^A P \rightarrow {}_{Z-2}^{A-4} D + ^4_2 \text{He} \]

β - Decay

\[ {}_Z^A P \rightarrow {}_{Z+1}^A D + ^0_{-1} e \]

γ – Decay

\[ {}_Z^A P^* \rightarrow {}_Z^A P + \gamma \]
**The Neutrino**

⇒ The existence of the neutrino was proposed in 1930 to account for the missing energy observed in β decays.

⇒ The existence of the neutrino was finally verified in 1956.

⇒ The neutrino interacts very weakly with matter.

⇒ The average neutrino can penetrate one light year (about 6 trillion miles) of lead without interacting.

⇒ Every second, trillions of neutrino pass through our body.

**Question:** If neutrinos interact so weakly with matter, how do we detect them???

**Answer:** With a really big detector!!!
Radiation Detectors

⇒ Radiation detectors work by detecting the ionization that results when $\alpha$, $\beta$, or $\gamma$-rays pass through matter.

ex: Geiger counters, scintillation counters, cloud chambers, bubble chambers, …

Geiger Counter

⇒ $\alpha$, $\beta$, or $\gamma$-rays entering the detector ionize gas molecules.
**Geiger Counter**

⇒ The produced electron accelerates towards the positive wire, ionizing other molecules in its path.

⇒ More electrons are freed which ionize more gas molecules and so on …

⇒ The avalanche of electrons creates a pulse of current in the detector.