

# Particle Physics

## Atoms

The word atom is derived from the Greek word "atomos", meaning indivisible or uncuttable

## The Nuclear Model

This model was coined by Ernest Rutherford in 1911

The model described the atom as a tiny, dense, positively charged core called a nucleus, in which nearly all the mass is concentrated, around which the light, negative constituents, called electrons, circulate at some distance, much like planets revolving around the Sun.

## Rutherford's Scattering experiment

In this experiment in 1912 Rutherford surrounded a Alpha particle in a collimator<sup>[1]</sup> Source with a thin sheet of gold<sup>[2]</sup> and around the sheet of gold is an alpha particle detector.

- Observation** : 99% of the  $\alpha$  particles emitted from the source will be received by the detector  
**Conclusion** : Most of the volume occupied by the atom is empty space, i.e. : The nucleus occupies a very small volume compared to the rest of the volume occupied by the atom.
- Observation** : A few number of  $\alpha$  particles are deviate with a small angle  
**Conclusion** : The nucleus is positively charged
- Observation** : Very few numbers of  $\alpha$  particles backscatter  
**Conclusion** : Most of the mass of the atom is concentrated in the nucleus

- Important Note**

- The diameter of an **atom** is approximately  $10^{-10}$  m
- The diameter of a **nucleus** is approximately  $10^{-14}$  m

## Radioactive Nucleus

- In nuclear physics there are a number of properties that are conserved
- A radioactive nucleus (mother nucleus) decays into the daughter nucleus, emitting radioactive radiation in an effort to become stable

3 types of nuclear radiation

- $\alpha$  Alpha particles
- $\beta$  Beta particles
- $\gamma$  Gamma waves

- Note**

- The daughter nucleus does not have to be stable
- The daughter nucleus does not have to emit the same radiation type as the mother nucleus



- A** → Atomic Mass / Nucleon Number
- Z** → Atomic Number

**u** → Unified atomic mass : it is the mass of one proton or neutron

$$1u = 1.66 \times 10^{-27} Kg$$

- Mass in  $Kg = A \times u$

**Isotopes** : Nuclei of the same element, same number of protons but different number of **neutrons**

**Activation** : Turning a stable nucleus into a radioactive one by hitting it with a neutron or with  $\gamma$  radiation

## Alpha Particles ( $\alpha$ )

It is made up of 2 protons and 2 neutrons (The nucleus of  ${}^4_2He$ )

### Properties:

1. Has a few  $cm$  of range in air, before turning into  ${}^4_2He$
2. Can be totally stopped by a thin piece of paper
3. Has the greatest ionizing<sup>[3]</sup> effect
4. Has discrete energy levels
5. Has a speed from  $\frac{1}{10}c$  to  $\frac{9}{10}c$
6. It is affected by electric and magnetic fields

## Gamma Rays ( $\gamma$ )

electromagnetic waves with 0 mass

### Properties:

1. Has a very wide range in air
2. Can be totally stopped by a thick shield of lead  $\approx 12\text{ cm}$
3. Has the least ionizing effect
4. Has discrete energy levels
5. Has a speed of  $c$  in air
6. **Not** affected by electric or magnetic fields



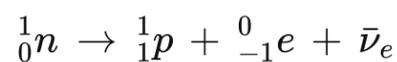
- \*  $\rightarrow$  Excited atom, i.e.: will emit excess energy in the form of  $\gamma$  rays without any change in protons or neutrons

## Beta Particles ( $\beta$ )



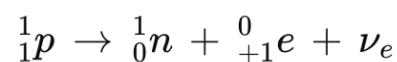
Fast moving negative electrons

- Emitted from a neutron decaying into a proton



Fast moving positive electrons

- Emitted from a proton decaying into a neutron



## Annihilation radiation

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## Quark Theory

**Quarks** : subatomic elementary particles that make up protons, neutrons, etc...

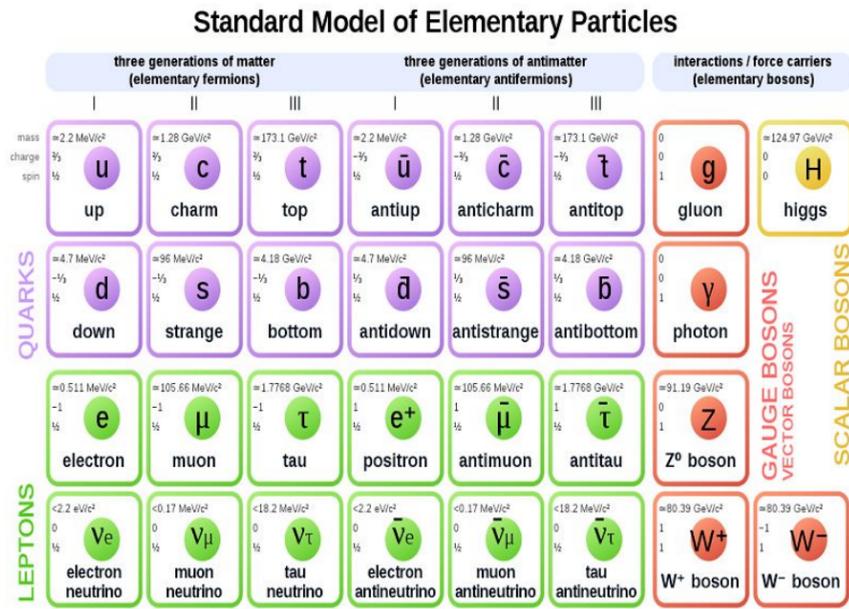
## Theory of Strong Forces

Very strong force of attraction between particles in the nucleus 100x stronger than the force of repulsion between protons

**hadron** : a composite subatomic particle made of two or more quarks held together by the strong interaction.

- **Remark** :  $\beta$  particle emission is due to the weak interaction between hadrons

# The Standard Model Of Particle Physics



**Baryons** : Particles composed of **3** quarks

**Mesons** : Particles composed of **2** quarks

- In Syllabus**

Type	Up	Down	Charm	Strange	Top	Bottom
Symbol	$u$	$d$	$c$	$s$	$t$	$b$
Charge	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$

Type	Anti-Up	Anti-Down	Anti-Charm	Anti-Strange	Anti-Top	Anti-Bottom
Symbol	$\bar{u}$	$\bar{d}$	$\bar{c}$	$\bar{s}$	$\bar{t}$	$\bar{b}$
Charge	$-\frac{2}{3}$	$+\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$

1. A collimator is a device which narrows a beam of particles or waves.↔
2. Because it was one of the thinnest materials they could produce at the time.↔
3. Neutral atom gaining or losing electrons, usually losing↔