

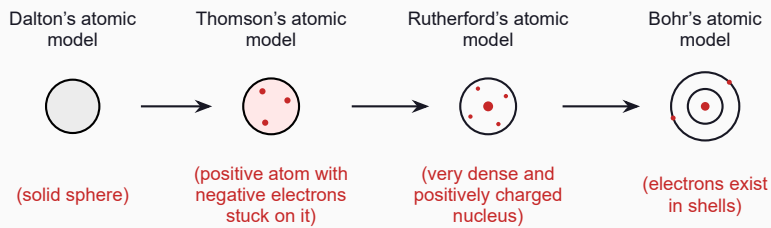
Particle Physics

Chapter 14 / AS Level / Apollo Physics 9702

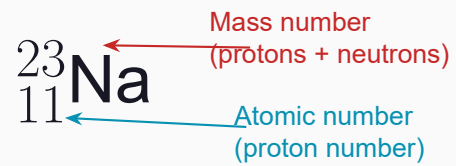


Atomic Models, Structure of the Atom, and Isotopes

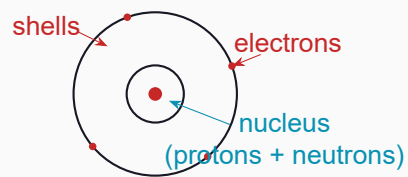
Historical atomic models



Nuclear notation



Structure of atom



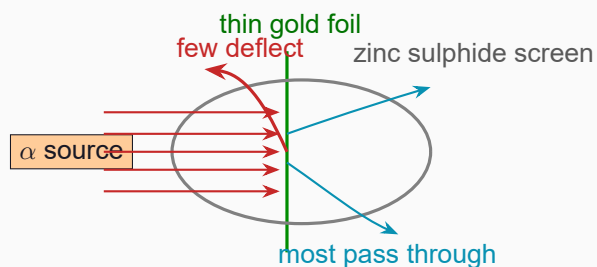
Isotopes

Atoms of the same element with same number of protons but different number of neutrons.

Mass number, A	number of protons + neutrons
Atomic number, Z	number of protons
Neutron number	$A - Z$

Geiger-Marsden Gold Foil Experiment and Nuclear Density

Geiger-Marsden gold foil experiment



- Most of the alpha particles were able to pass through.
⇒ Atom is mostly empty.
- A few deflected at large angles and very few bounced back.
- ⇒ A very small and dense positively charged nucleus exists in the middle.

Charge of alpha particle

Alpha particle: ${}^4_2\alpha$, charge = +2.

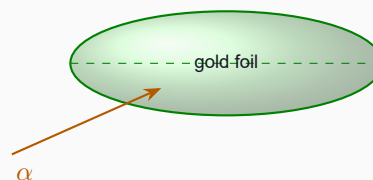
How dense is the nucleus?

Carbon atom: $6p$ and $6n$.

- mass = $12u$, where $1u = 1.66 \times 10^{-27} \text{ kg}$
- diameter of nucleus $\approx 10^{-14} \text{ m}$
- assuming nucleus as a sphere

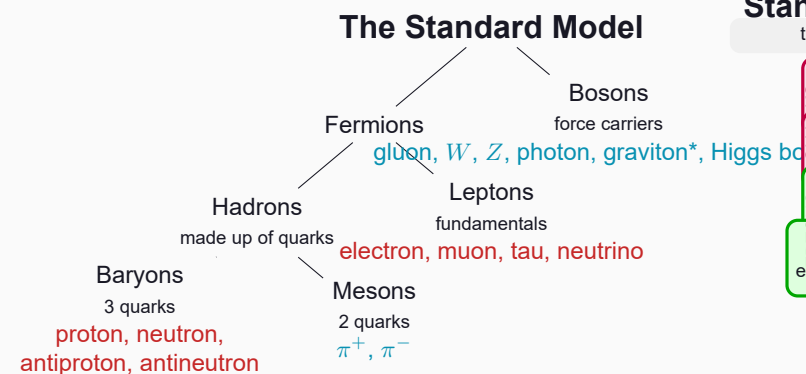
$$\rho = \frac{m}{V} = \frac{12(1.66 \times 10^{-27})}{\frac{4}{3}\pi(10^{-14})^3} \approx 4 \times 10^{15} \text{ kg m}^{-3}.$$

Extremely dense!



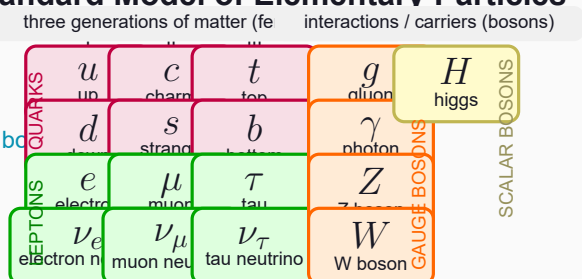
The Standard Model

Classification



Standard Model of Elementary Particles

Standard Model of Elementary Particles



Four fundamental forces of universe

1. Strong nuclear force
2. Electromagnetic force
3. Weak nuclear / interaction force
4. Gravitational force

Decreasing strength of force ↓

(Experienced by quarks and leptons.)

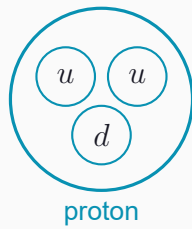
Quarks and Charge Calculations

Quarks

6 flavours of quarks

up quark (u)	$+\frac{2}{3}e$	charm quark (c)	$+\frac{2}{3}e$	top quark (t)	$+\frac{2}{3}e$
down quark (d)	$-\frac{1}{3}e$	strange quark (s)	$-\frac{1}{3}e$	bottom quark (b)	$-\frac{1}{3}e$

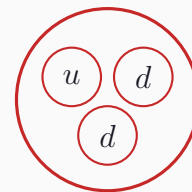
Proton: uud



proton

$$u + u + d = +\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +\frac{3}{3}e = \boxed{+1e}.$$

Neutron: udd



neutron

$$u + d + d = +\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = \boxed{0}.$$

Antimatter and the Neutrino

Antimatter

- Particle having same mass but opposite charge.
- When matter collides with its corresponding antimatter, they annihilate one another.
- Energy is released as electromagnetic radiation.

Particle	Antiparticle
+ proton (uud)	– antiproton ($\bar{u}\bar{u}\bar{d}$)
0 neutron (udd)	0 antineutron ($\bar{u}\bar{d}\bar{d}$)
– electron (e^-)	+ positron (e^+)
0 neutrino (ν)	0 antineutrino ($\bar{\nu}$)

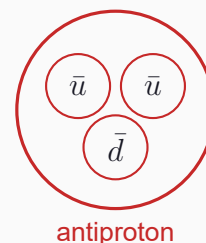
Symbol of neutrino

neutrino (ν), antineutrino ($\bar{\nu}$).

Antiproton charge

$$\bar{p} = \bar{u}\bar{u}\bar{d}$$

$$\bar{u} + \bar{u} + \bar{d} = -\frac{2}{3}e - \frac{2}{3}e + \frac{1}{3}e = \boxed{-1e}.$$



antiproton

HARDER PARTICLES!

- Produced during beta decay.
- No charge.
- Negligible mass.

Radioactivity

Definition

The phenomenon of emission of radioactive radiations from the nucleus of an unstable atom.

Why it happens

Nucleus gets unstable when the number of nucleons inside it becomes more than it can hold at that size.

Random process

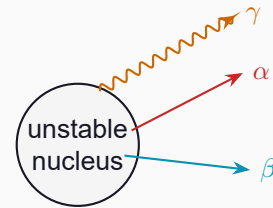
Every nucleus has equal chance to decay. It cannot be predicted which nucleus is going to decay when.

Spontaneous process

There is no control over this reaction; changing external conditions like temperature and pressure has no effect on its activity.

Types of radiations

1. Alpha rays
2. Beta rays
 - (a) beta positive (positron)
 - (b) beta negative (electron)
3. Gamma rays



Alpha Rays and Beta Negative

ALPHA RAYS

Nuclear symbol:	${}^4_2\alpha$
Nature:	Helium nucleus ($2p + 2n$)
Charge:	+2
Mass:	$4u$, where $1u = 1.66 \times 10^{-27} \text{ kg}$
Ionization power:	Greatest. Removes electrons from air molecules and produces ions.
Penetration power:	Weakest. Large particle so easily stopped by a piece of paper.
Range:	$\sim 10 \text{ cm}$, commonly 4 cm to 5 cm
Equation:	${}^{235}_{92}\text{U} \rightarrow {}^4_2\alpha + {}^{231}_{90}\text{X} + \text{energy}$

$$E = mc^2$$

BETA NEGATIVE

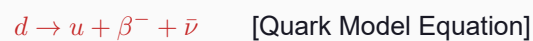
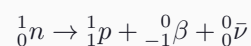
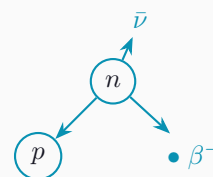
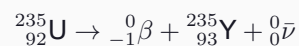
Nuclear symbol:	${}^0_{-1}\beta$
Nature:	fast moving electron (variable speed)
Charge:	-1
Mass:	$9.11 \times 10^{-31} \text{ kg}$
Ionization power:	Less than alpha due to less charge.
Penetration power:	Greater than alpha due to smaller size. 10 mm to 20 mm thick aluminium sheet
Range:	few metres ($\sim 10 \text{ m}$)
Equation:	—

Beta Positive and Equations of Beta Negative

BETA POSITIVE (Antimatter)

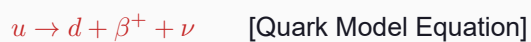
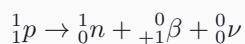
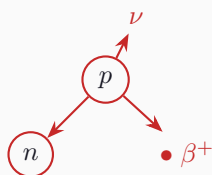
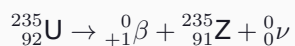
Nuclear symbol:	${}_{+1}^0\beta$
Nature:	fast moving positron (variable speed)
Charge:	+1
Mass:	$9.11 \times 10^{-31} \text{ kg}$
Ionization power:	Less than alpha due to less charge.
Penetration power:	Greater than alpha due to smaller size; stopped by 10 mm to 20 mm thick aluminium sheet.
Range:	short range as it annihilates.
Equation:	—

Equations of beta negative



Equations of Beta Positive and Gamma Rays

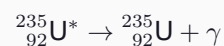
Equations of beta positive



GAMMA RAYS

Nuclear symbol:	γ
Nature:	High frequency electromagnetic radiation
Charge:	0
Mass:	0
Range:	several metres (~ 50 m)
Ionization power:	Least. It does not have charge but it can move electrons.
Penetration power:	Greatest. No size; stopped by 4 cm thick lead or 15 cm thick concrete wall.

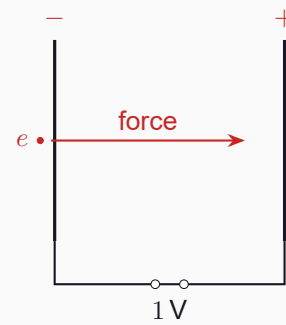
Equation



Quantities Conserved During Nuclear Reaction and Electron-Volts

Quantities conserved during nuclear reaction

1. Proton number
2. Mass number
3. Charge
4. Momentum
5. Mass-energy conserved



Electron-volts (eV)

- It is a unit of energy.
- It is the energy gained when an electron is accelerated through a potential difference of 1 V.

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$V = \frac{W}{q} \quad \text{or} \quad V = \frac{E}{q}$$

$$E = Vq = (1 \text{ V})(1e) = 1 \text{ eV}$$

$$E = (1 \text{ V})(1.6 \times 10^{-19} \text{ C}) = 1.6 \times 10^{-19} \text{ J}.$$