PARTICLE PHYSICS

PHYSICS BY

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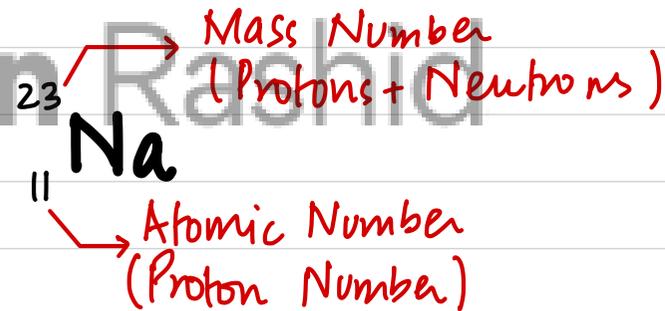
Dalton's Atomic Model
(Solid sphere)

Thomson's Atomic Model
(A positive atom with negative electrons stick on it)

Rutherford's Atomic Model
(A very dense & positively charged nucleus)

Bohr's Atomic Model
(Electrons exist in shells)

Structure of Atom

Shells (electrons)

Nucleus (protons + neutrons)

$^{23}_{11}$ Na

Mass Number (Protons + Neutrons)
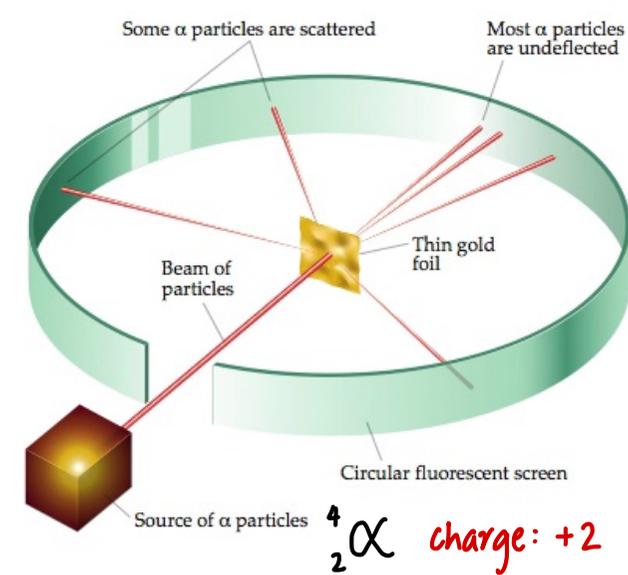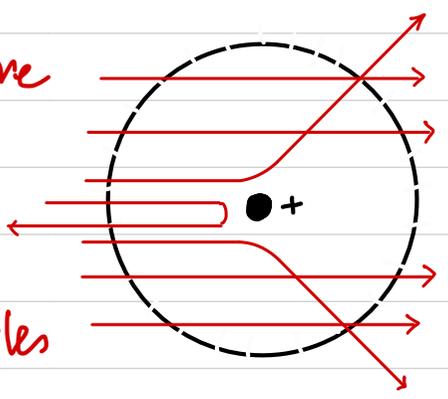
Atomic Number (Proton Number)

Isotopes: Atoms of the same element with same no. of protons but diff no. of neutrons.

Gieger - Marsden Gold Foil Experiment

☑ Most of the Alpha particles were able to pass through
→ Atom is mostly empty.

☑ A few deflected at large angles
☑ Very few bounced back
→ A very small and dense positively charged nucleus exists in the middle.

Some α particles are scattered
Most α particles are undeflected
Thin gold foil
Beam of particles
Circular fluorescent screen
Source of α particles $^4_2\alpha$ charge: +2

How dense is the nucleus?

Carbon atom: 6p and 6n
- mass = 12 u   & 1u: 1.66×10^{-27} kg
- diameter of nucleus = 10^{-14} m
(Assuming nucleus as sphere)

$$\rho = \frac{m}{V}$$

$$\rho = \frac{12 \times 1.66 \times 10^{-27}}{\frac{4}{3}\pi(10^{-14})^3}$$
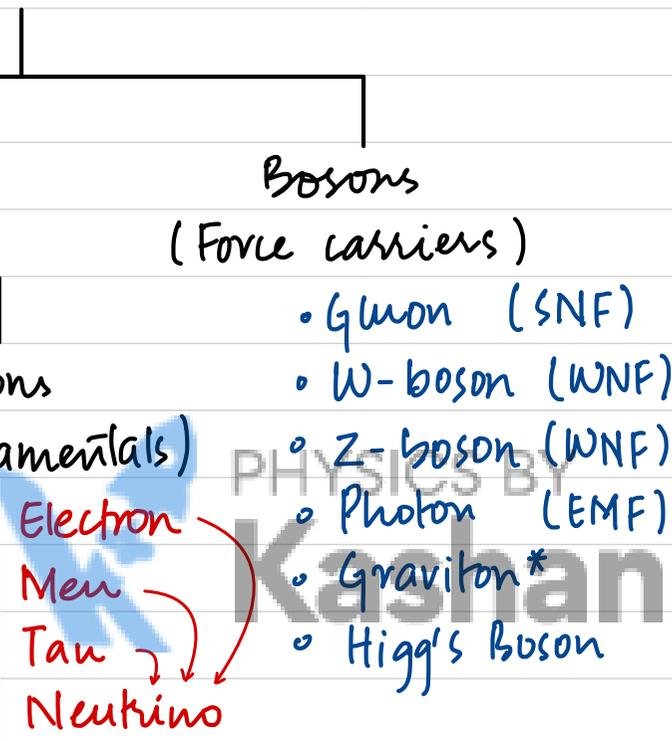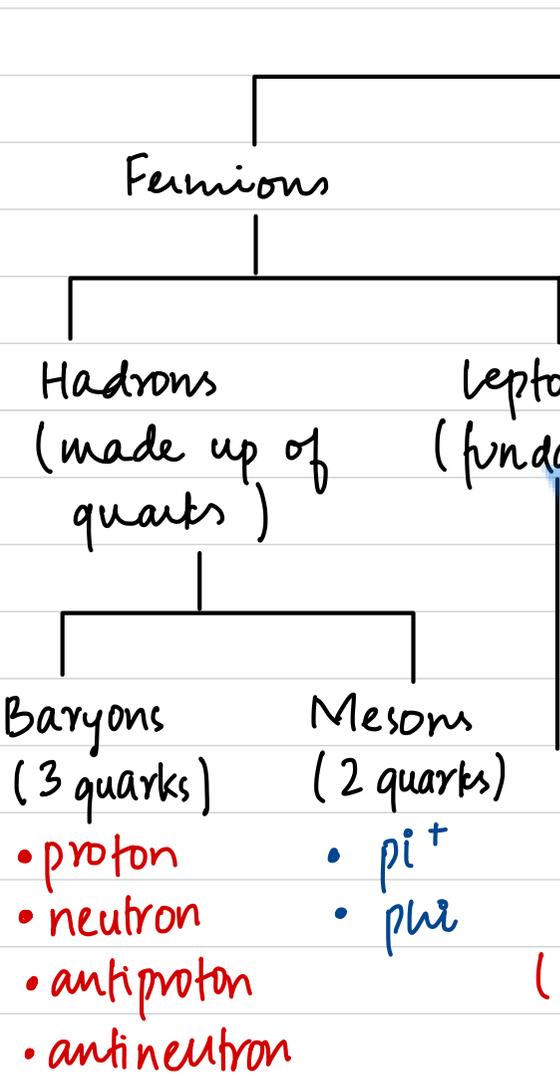
$$\rho = * \times 10^{15} \ kgm^{-3}$$
(extremely dense!)

1000 000 000 000 000 kg
in 1m³

The Standard Model

Fermions ──── Bosons
(Force carriers)

- Gluon (SNF)
- W-boson (WNF)
- Z-boson (WNF)
- Photon (EMF)
- Graviton*
- Higg's Boson

Standard Model of Elementary Particles

	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass charge spin	≃2.2 MeV/c² $\frac{2}{3}$ $\frac{1}{2}$ **u** up	≃1.28 GeV/c² $\frac{2}{3}$ $\frac{1}{2}$ **c** charm	≃173.1 GeV/c² $\frac{2}{3}$ $\frac{1}{2}$ **t** top	0 0 1 **g** gluon	≃124.97 GeV/c² 0 0 **H** higgs
QUARKS	≃4.7 MeV/c² $-\frac{1}{3}$ $\frac{1}{2}$ **d** down	≃96 MeV/c² $-\frac{1}{3}$ $\frac{1}{2}$ **s** strange	≃4.18 GeV/c² $-\frac{1}{3}$ $\frac{1}{2}$ **b** bottom	0 0 1 **γ** photon	SCALAR BOSONS
	≃0.511 MeV/c² -1 $\frac{1}{2}$ **e** electron	≃105.66 MeV/c² -1 $\frac{1}{2}$ **μ** muon	≃1.7768 GeV/c² -1 $\frac{1}{2}$ **τ** tau	≃91.19 GeV/c² 0 1 **Z** Z boson	GAUGE BOSONS
LEPTONS	<1.0 eV/c² 0 $\frac{1}{2}$ **ν_e** electron neutrino	<0.17 MeV/c² 0 $\frac{1}{2}$ **ν_μ** muon neutrino	<18.2 MeV/c² 0 $\frac{1}{2}$ **ν_τ** tau neutrino	≃80.39 GeV/c² ±1 1 **W** W boson	VECTOR BOSONS

Fermions

Hadrons (made up of quarks) ──── Leptons (fundamentals)

Hadrons:
- Baryons (3 quarks)
- Mesons (2 quarks)

Baryons:
- proton
- neutron
- antiproton
- antineutron

Mesons:
- pi⁺
- phi

Leptons:
- Electron
- Meu
- Tau
- Neutrino

4 Fundamental Forces of Universe

(Exp. by Quarks)→ 1. Strong Nuclear Force

2. Electromagnetic force

(Quarks + Leptons) 3. Weak Nuclear Interaction Force

4. Gravitational Force

Decreasing Strength of force

Quarks

6 flavors of quarks
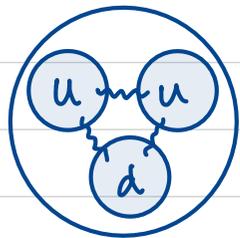
up quark (u) $+\frac{2}{3}e$ charm quark   top quark

down quark (d) $-\frac{1}{3}e$ strange quark (s) $-\frac{1}{3}e$ bottom quark

Proton : u u d   Neutron : u d d

$u + u + d$

$+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e$

$+\frac{3}{3}e = +1e$

$u + d + d$

$+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e$

0

Antimatter

→ Particles having same mass but opposite charge.

→ When matter collides with its corresponding antimatter, they annhialate one another. Energy is released as electromagnetic radiations.

+ proton (uud)   − antiproton ($\bar{u}\bar{u}\bar{d}$)

0 neutron (udd)   0 antineutron ($\bar{u}\bar{d}\bar{d}$)

− electron (e)   + positron ($\bar{e}$)

0 neutrino (ν)   0 antineutrino ($\bar{\nu}$)

     symbol ℓ

antiproton : $\bar{u}\bar{u}\bar{d}$ $u = +\frac{2}{3}e$ $d = -\frac{1}{3}e$

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

$-\frac{2}{3}e - \frac{2}{3}e + \frac{1}{3}e$

$-1e$

Neutrino (ν)   KHABEES PARTICLES!

• Produced during Beta decay.
• No charge
• Negligible mass

Radioactivity

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

Nucleus gets unstable when the no. of nucleons inside it become more than it can hold at that size.

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

- It is a SPONTANEOUS PROCESS
  There is no control over this reaction. Changing external conditions like Temp & Pressure has no effect on its activity.

Type of Radiations

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

ALPHA RAYS	BETA NEGATIVE
Nuclear Symbol: $^4_2\alpha$	Nuclear Symbol: $^0_{-1}\beta$
Nature: Helium nucleus (2p+2n)	Nature: fast moving electron (variable speed)
Charge: +2	Charge: -1
Mass: 4u (1u = 1.66×10⁻²⁷ kg)	Mass: 9.11 × 10⁻³¹ kg
Ionization Power: Greatest	Ionization Power: Less than Alpha due to less charge.
Removes electrons from neighbouring air molecules and produces ions.	
Penetration Power: Weakest	Penetration Power: Greater than Alpha due to smaller size.
Large particle so easily stopped by a piece of paper.	Stopped by <u>10 mm to 20 mm</u> thick Aluminium sheet.
Range: ~10 cm (4 cm to 5 cm)	Range: few meters (~10 m)
Equation:	Equation: —

$$^{235}_{92}U \longrightarrow \, ^4_2\alpha + \, ^{231}_{90}X + energy$$

$$E = mc^2$$

BETA POSITIVE (Antimatter)

Nuclear Symbol: $_{1}^{0}\beta$

Nature: fast moving positron (variable speed)

Charge: +1

Mass: 9.11×10^{-31} kg
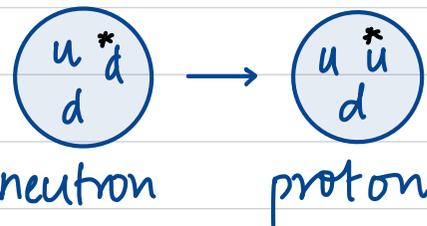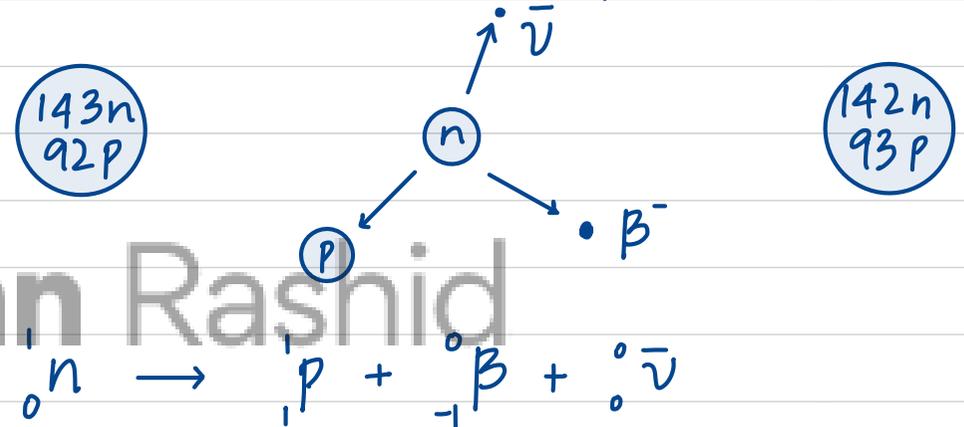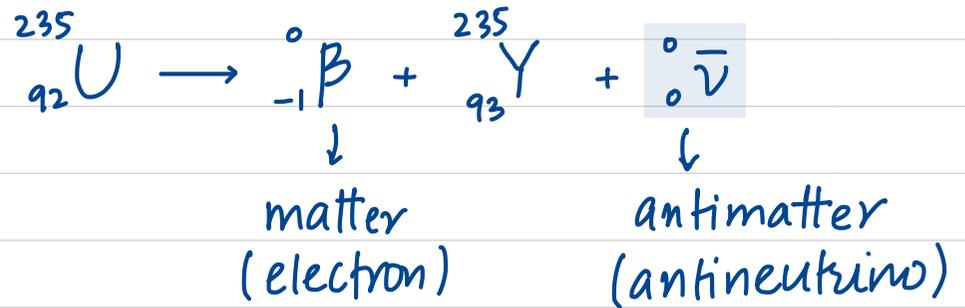
Ionization Power: Less than Alpha due to less charge.

Penetration Power: Greater than Alpha due to smaller size.
Stopped by 10 mm to 20mm thick Aluminium sheet.
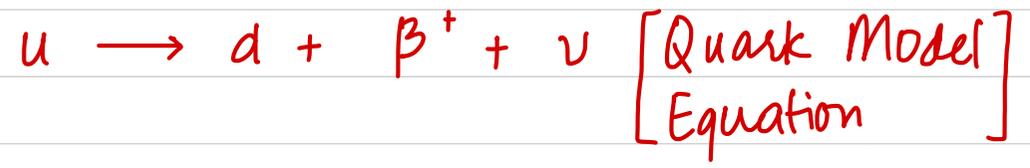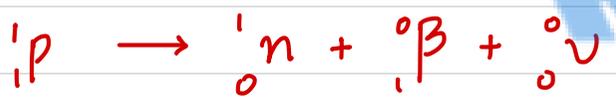
Range: Short range as it annialates!
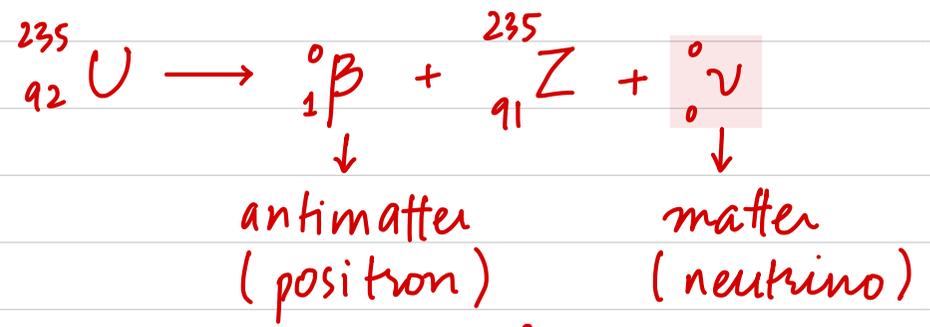
Equation: —

Equations of Beta Negative

$$_{92}^{235}U \longrightarrow \, _{-1}^{0}\beta + \, _{93}^{235}Y + \, _{0}^{0}\bar{\nu}$$

matter (electron)   antimatter (antineutrino)

$$_{0}^{1}n \longrightarrow \, _{1}^{1}p + \, _{-1}^{0}\beta + \, _{0}^{0}\bar{\nu}$$

neutron → proton

$$d \longrightarrow u + \beta^{-} + \bar{\nu} \quad \left[\begin{array}{l}\text{Quark Model}\\\text{Equation}\end{array}\right]$$

Equations of Beta Positive

$$^{235}_{92}U \longrightarrow ^{0}_{1}\beta + ^{235}_{91}Z + ^{0}_{0}\nu$$

antimatter   matter
(positron)   (neutrino)

$$^{1}_{1}p \longrightarrow ^{1}_{0}n + ^{0}_{1}\beta + ^{0}_{0}\nu$$

proton   neutron

$$u \longrightarrow d + \beta^{+} + \nu \quad \left[\begin{array}{l}\text{Quark Model}\\\text{Equation}\end{array}\right]$$
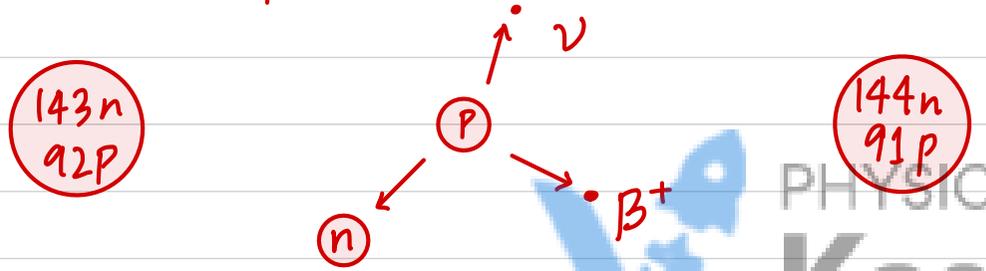
GAMMA RAYS

Nuclear Symbol: γ
Nature: High frequency E.M. radiation
Charge: 0
Mass: 0
Range: several meters ($\sim 50m$)
Ionization Power: Least
It doesnot have a charge but its energy can remove electrons
Penetration Power: Greatest
No size. Stopped by 4cm thick lead block or thick concrete wall
Equation:

$$^{235}_{92}U^{*} \longrightarrow ^{235}_{92}U + \gamma$$
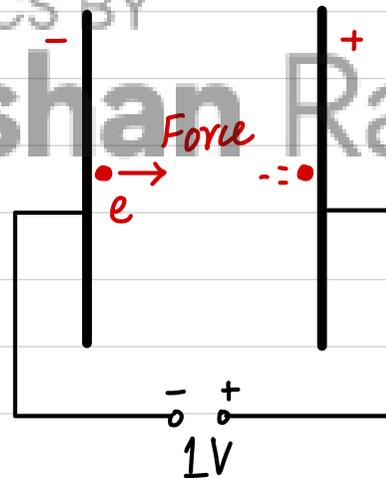
energetically excited   stable
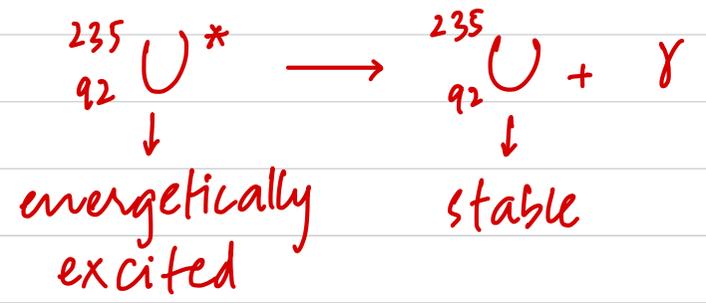
Quantities Conserved during nuclear reaction

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 1V.

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

$V = \dfrac{W}{q}$ or $V = \dfrac{E}{q}$

Force

so $E = Vq$

$E = (1V)(1e)$
$E = 1eV$

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

1V