PARTICLES AND ANTIPARTICLES

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PARTICLES AND ANTI-PARTICLES

- Dirac predicted theoretically the existence of antiparticles for the electron. He actually postulated that every particle has antiparticles. The antiparticles of a given particles has exactly the same mass, spin, and life time (if unstable) but an opposite charge (if any).

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Electron and positron

- The first antiparticles known was positron which was discovered by Anderson in 1932. It is a positively charged electron, i.e., it has the same mass and the same spin as an electron but opposite charge. When an electron and a positron come in contact with each other.

$e^+ + e^- = 2^Y$

Proton and antiproton

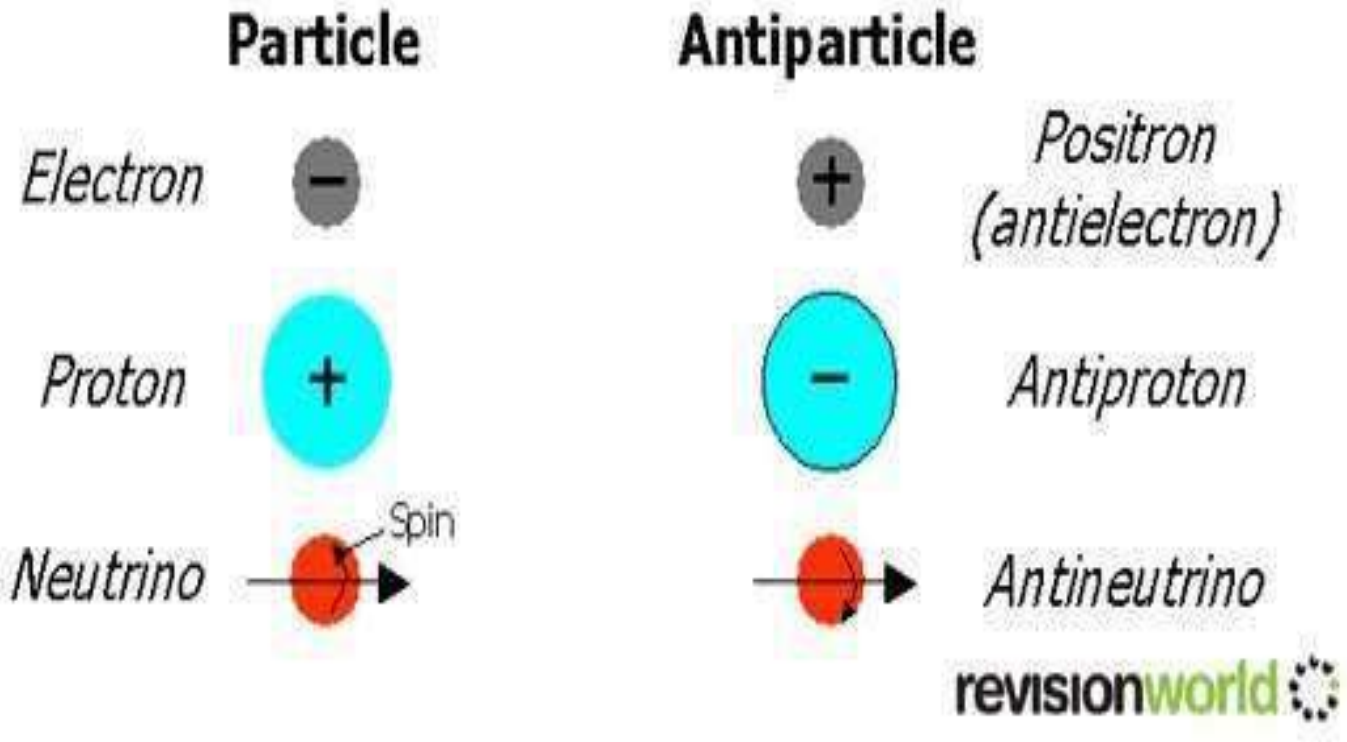
- The antiparticles of proton are called the antiproton. It has the same mass as a proton, but an opposite charge and the same spin as a proton but an opposite magnetic moment. Thus it is a negative proton and is denoted by p^-. It was established in1955 by Segre, Chamberlain and their collaborators.

Neutron and Antineutron

It is much harder to detect an antineutron because it has no charge. Both neutron and antineutron have zero charge and the same mass but antineutron is supposed to have an internal charge distribution to that of neutron.

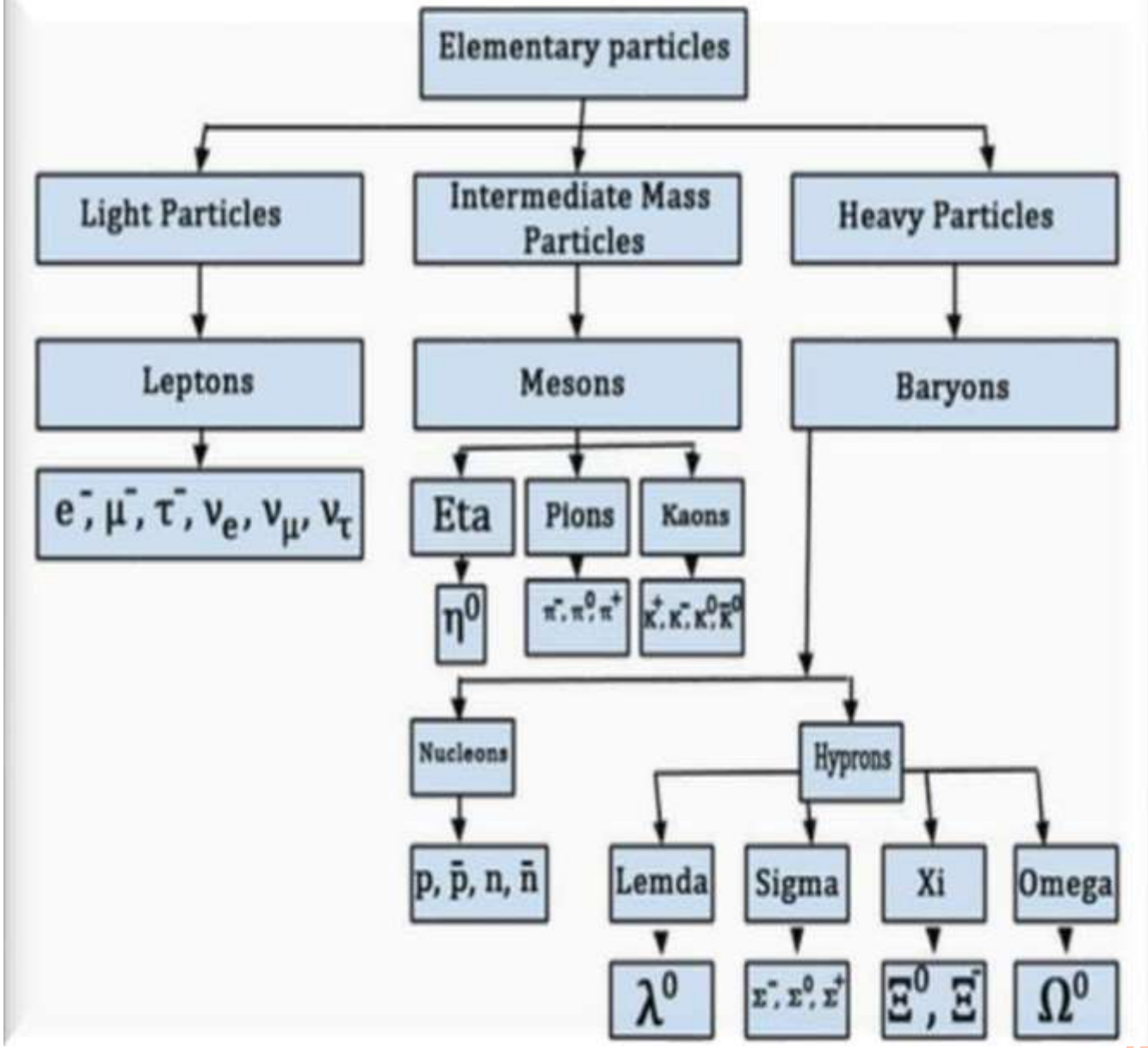
Neutrino and antineutrino

The antiparticles of neutrino ν are antineutrino. The neutrino spins counter $(\bar{n})$ckwise when viewed from behind from behind, while antineutrino spins clockwise.



CLASSIFICATION OF ELEMENTARY PARTICLES

On the basis of the characteristic properties such as mass, spin, intrinsic angular momentum and the nature of reactions they can undergo, the elementary particles are usually classified into following groups.


Elementary particles
Light Particles
Intermediate Mass Particles
Heavy Particles
Leptons
Mesons
Baryons
$e^-, \mu^-, \tau^-, \nu_e, \nu_\mu, \nu_\tau$
Eta
Pions
Kaons
η^0
π^-, π^0, π^+
$K^+, K^-, K^0, \bar{K}^0$
Nucleons
Hyprons
p, $\bar{p}$, n, $\bar{n}$
Lemda
Sigma
Xi
Omega
λ^0
$\Sigma^-, \Sigma^0, \Sigma^+$
Ξ^0, Ξ^-
Ω^0

PHOTONS

Photon is a quantum of electromagnetic radiation. It is a stable particle with zero charge and zero rest mass. It is a bosom because its spin $\frac{1}{2}$s unity. It has energy given by Planck's equation E=hv where v is the frequency of radiation. It has an equivalent mass given by Einstein equation $E=mc^2$. therefore,

$$M = \frac{E}{c2} = \frac{hv}{c2} = \frac{h}{c2} \cdot \frac{c}{\lambda} = \frac{h}{c\lambda}$$

Leptons

These are light weight elementary particles. They have a spin equal to and are, therefore, fermions. They are characterized by their Spin-momentum .The leptons are $= \frac{1}{2} \cdot \frac{h}{2\pi} = \frac{h}{2\pi}$

stable except muons. They interact weakly with other particles and occur as particles and antiparticles.

The members of lepton class are electron and positron (e^- , e^+), muons (μ^- , μ^+), electron-neutrinos (v_e, $_e$) and muon-neutrinos (v_μ, $_\mu$).

Electron and positron

Electron is stable atomic particles of mass 9.1×10^{-31} kg and negative charge of 1.6×10^{-19} coulomb. It has spin quantum number s= and so its angular momentum has magnitude . Therefore, it is a fermion.

Positron is the antiparticle of electron. It is identical with electron in all respects except that it is positively charged. When electron and positron come in contact, they annihilate each other producing two Y-photons:

$$e^+ + e^- = Y + Y$$

Muons (or m-Mesons)

Mu-mesons, called muons, were discovered by Anderson in 1936. μ-mesons exist as both negative and positive and are denoted by μ^+ and μ^- respectively. They are created as π-meson decay in cosmic radiations.

μ^+ and μ^- mesons have the same spin of $\frac{1}{2}$ and resemble with positron and electron respectively in all respects except the following:

Muons are heavier than electron or positron. They have the same rest mass of 207 m_e is the mass of electron.

Both μ^+ and μ^- mesons are unstable (unlike electron and positron) having an average life of 2.2×10^{-6} sec. they decay spontaneously into an electron or positron, a μ-neutrino and an ordinary neutrino according to the following scheme:

$$\mu^+ \rightarrow e^+ + {}_{\mu} + \nu$$

$$\mu^- \rightarrow e^- + \nu_{\mu} +$$

Energy of 10^5 MeV is released in the decay.

Neutrinos and Antineutrinos:

These particles have negligible rest mass and no charge. They have a spin value of and a spin angular momentum $\frac{1}{2}$.

Neutrinos are of two $\frac{h}{2}$inds. Those associated with electrons are called simply neutrinos (v) or electron neutrinos (v_e) while those associated with muons are called μ-neutrinos (v_μ). Both of these neutrinos have their antiparticles denoted by

(or $_e$) and $_\mu$ respectively. They participate in weal interaction with matter and hence their detection causes difficulty. In 1956, however, a nuclear reaction induced by neutrinos was actually observed

MESONS

Mesons are the agent of interaction between particles inside the nucleus. Mesons are middle weight particles having masses intermediate between the electrons and protons. They are all bosons having zero spin. They possess zero intrinsic (spin) angular momentum and are unstable. Variety of mesons is now known. They include:

Π π -mesons or pions

π-mesons were discovered in 1947 in the cosmic rays. They can exist in three states: π^+, π^- and π^0. The π^+ and π^- are antiparticles of each other while π^0 (neutral pi-meson) has no charge and it is its own anti particle.

π^+ and π^- mesons have a rest mass of 273 m_e (m_e being rest mass of electron) while the rest mass of π^+ meson is slightly less, equal to 264 m_e.

Pions interact strongly with nucleus

They are produced by collisions of high energy (kinetic energy 140 M_eV) protons with nucleons (proton or neutron) according to the following:

$$p + p = p + n + \pi^+$$
$$p + n = p + p + \pi^-$$
$$p + p = p + p + \pi^0$$

They are also produced by annihilation of proton-antiproton and neutron-antineutron:

$$p + p^- = \pi^+ + \pi^- + \pi^0$$
$$n + n = \pi^+ + \pi^- + \pi^0$$

The π-mesons are unstable particles. The average life time of charged π-mesons (π^0 and π^-) is of the order of 10^{-8} sec while that of neutral π-mesons (π^0) is still shorter ($=9\times10^{-17}$sec). Consequently, only a fraction of cosmic ray π-mesons can reach and they decay in flight by weak interaction into corresponding muons and μ-neutrinos:

$$\Pi^+ \rightarrow \mu^+ + \mu$$
$$\pi^- \rightarrow \mu^- + \mu$$

μ^+ and μ^- further decay into e^+ and e^- respectively.

The neutral π-meson (π^0) decays by an electromagnetic interaction into two high energy Υ-photons:

$$\pi \rightarrow \Upsilon + \Upsilon$$

K-Mesons (or Kaons)

K-Mesons is a heavier class of mesons. They exist as K^+ and its antiparticles k^{-1} and also as k^0 and its antiparticles ^{0}.

The charged K-mesons (K^+ and K^-) have rest masses of $966m_e$, spin zero and mean lives $1.2x10^{-8}$ sec. they commonly decay giving rise to two or three less massive particles:

$$K^+ \rightarrow \pi^+ + \pi^+ + \pi^-$$

$$K^{\pm} \rightarrow \pi^{\pm} + \pi^o$$

$$K^+ \rightarrow \mu^+ + V_\mu$$

$$K^+ \rightarrow \pi^+ + \pi^o + \pi^o$$

The K^0 mesons are produced through strong interaction of high energy pions and protons:

$$\pi^- + p^+ \rightarrow \Lambda^0 + K^o$$

Where ^{0} is lambda particle.

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η-Mesons: The central eta meson (η^+) was discovered in1961. It has a rest mass of 1073 m_e and a zero spin value (boson). Its average half life is 7×10^{-19} sec. in which it decays electromagnetically in two photons.

Baryons

There are heavy weight elementary particles, having their rest mass equal to or greater than that of nucleon (Proton and neutrons), but less than that of deuteron. They have spin values of $\frac{1}{2}$ and hence are fermions. They are strongly interacting and posses intrinsic angular momentum $\frac{h}{2}$.

Except protons, all baryonsare unstable.

Baryons have been grouped into two subclasses:

Nucleons

These are nuclear particles and include proton (p), neutron (n) and their anti particles, anti proton $(\bar{p})$ and anti neutron $(\bar{n})$. Proton has a mass 1836 m_e while neutron's mass Is 1839 m_e. They all have a spin of and are fermions.

Hyperons

The baryons possessing the rest mass greater than that of nucleons are called hyperons. They are unstable and have an average life time of the order of 10^{-10} sec. Their decay time is very much greater than the time of their formation (10^{-3} sec). Therefore, these particles, along with the K-mesons are called strange particles.

There are four types of hyperons

Lambda hyperons (Λ^0):- There are two lambda hyperons, which have zero charge and 2181 me, rest mass. They are represented by Λ^0 and anti particles of the other.

Sigma Hyperons: - There are six particles Σ^+, $\sum^-$, $\sum^0$ and their anti particlesΣ^+,Σ^-,Σ^o, they have respectively positive, negative and zero charges. Σ^+ is the lightest of all three particles having rest mass 2328 me.

Xi Hyperons: - There are four Xi-hyperons each with a ret mass of 2580 me. They are Ξ^- Ξ (with negative charge) and their anti particles.

Omega Hyperons: - $^-$ (with negative charge) and its anti particles.

The spin of all hyperons is except that of hyperons which have a spin of.


Thank
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