

The Standard Model of Particle Physics (Theory, not law) used to explain the existence of all particles that have been observed and forces that hold the atom together

Force - Push/Pull on object causing acceleration

New Definition Particles are force carriers - forces are brought about as a result of an exchange of particles

Fundamental Forces of Nature

- Strong (Nuclear) - Strongest force, but acts over a short distance
- Electromagnetic
- Weak - (Short Range nuclear force responsible for decay of some particles)
- Gravitational

Grand Unification Theory - Attempt to combine 3 forces

Classification of Matter

All particles can be classified according to the type of interaction they have with other particles

Hadrons - Particles that interact through all 4 fundamental forces (Protons & neutrons)

Leptons - Particles that interact w/ all forces except ^{nuclear} gravitational force

↳ Electrons, positrons & neutrinos

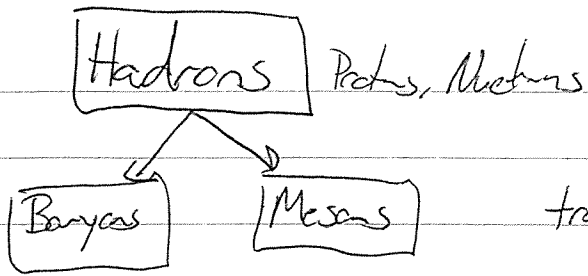
Positrons - Same mass as an electron but Positive Charge

e^+ mass = $9.11 \times 10^{-31} \text{ kg}$, Charge = $+1.6 \times 10^{-19} \text{ C}$

Neutrinos - Nuclear particle, ≈ 0 mass, but has energy & mass

Anti-Particles - A particle having the same mass and spin, but opposite charge

Ex. The Anti-Particle of an ~~proton~~ electron is a positron



Baryons - Elementary particle that can be transformed into a Proton ${}^1_0\text{P}$ or a Neutron ${}^1_1\text{n}$

Mesons - A particle of intermediate mass

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Quarks - Building Blocks of the nucleus PHI

Quarks are sub-atomic particles that make up the nucleus

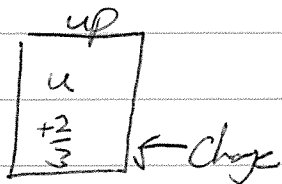
Quarks come in 2 charges $+\frac{2}{3}e$ or $-\frac{1}{3}e$

A proton is made up of 3 quarks up-up-down
 $proton = uud \quad \left(\frac{+\frac{2}{3}}{3} + \frac{+\frac{2}{3}}{3} - \frac{-\frac{1}{3}}{3}\right)e = +1e$

A neutron is made up of up-down-down
 $neutron = udd \quad \left(\frac{+\frac{2}{3}}{3} - \frac{-\frac{1}{3}}{3} - \frac{-\frac{1}{3}}{3}\right)e = 0e$

Individual quarks can not be observed - strong force which holds them together acts as a spring force as they get further apart

Molecule \rightarrow Atoms \rightarrow Nucleus \rightarrow Proton/Neutron \rightarrow Quark



What differentiates Up, Charm, top are their masses top is ~~the~~ heavier

Baryons - Composed of 3 quarks
 Heavy Particles (Protons, Neutrons)
 Charges must add to +1, 0, -1

Mesons - Particles composed of quark anti-quark pairs
 (other) intermediate mass

Bombard particles w/ particle accelerator to ~~create~~ break up the particle to create smaller particles.

u	-up	\bar{u} - "Anti-quark up"	\bar{d} Anti-down
$+\frac{2}{3}$		$-\frac{2}{3}$	$+\frac{1}{3}$
$\frac{3}{3}$		$\frac{3}{3}$	$\frac{3}{3}$

A mercury atom changes its energy levels from i to f . What electromagnetic spectrum does it fall into.

Find Freq $E = hf$

$$E_{\text{photon}} = E_i - E_f$$

$$-1.56 \text{ eV} - (-3.71 \text{ eV}) = 2.15 \text{ eV}$$

Convert to Joules

$$2.15 \text{ eV} \cdot \frac{1.6 \times 10^{-19} \text{ J}}{1 \text{ eV}} = 3.44 \times 10^{-19} \text{ J}$$

$$E_{\text{photon}} = hf$$

$$\cancel{5.19 \times 10^{-14} \text{ J}} = (6.63 \times 10^{-34} \text{ J s}) (\cancel{3.44 \times 10^{19} \text{ Hz}})$$

$$3.44 \times 10^{-19} \text{ J} = 6.63 \times 10^{-34} \text{ J s } f$$

$$5.18 \times 10^{14} \text{ Hz}$$

Yellow Light

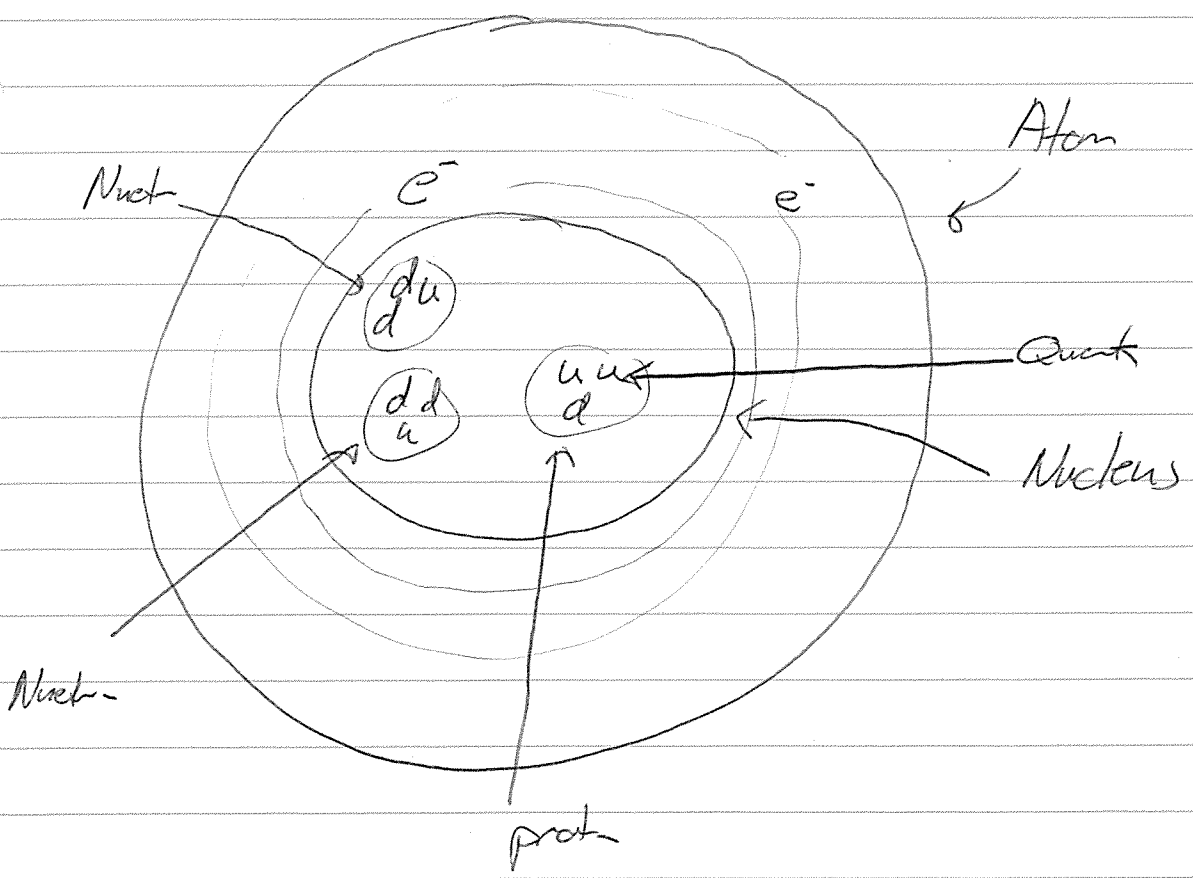
Quarks - One of the basic particles having charges of $\pm \frac{1}{3}e$ or $\pm \frac{2}{3}e$

- Make up elementary particles
- Never found separately *Explain*

e^- is no longer considered the smallest charge (Fundamental)

- Every Baryon is composed of 3 quarks
- Every Meson is a combination of a quark & anti-quark

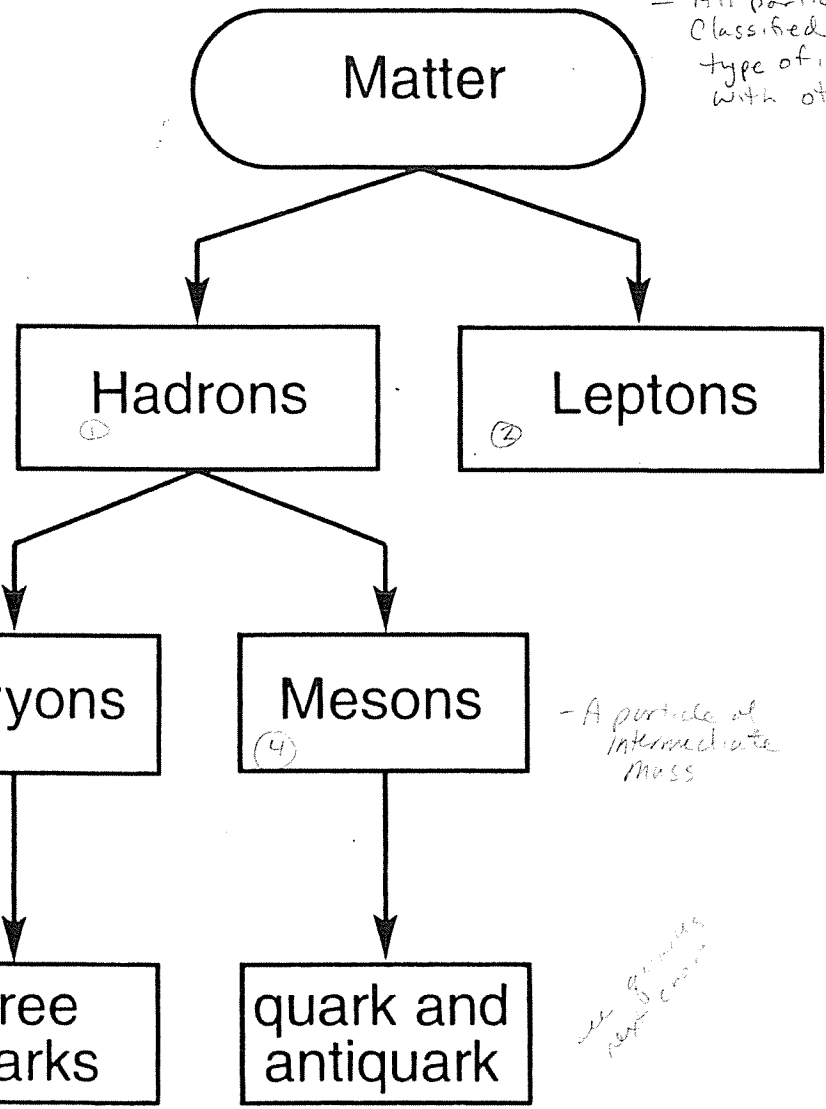
Quark Content of a proton: uud Neutron: ddu Baryons always add to 0, +1, -1



Classification of Matter

- Force - Force Carrier
- Strong - gluon
- electromagnetic - photon
- Weak - bosons
- gravitational - graviton

- Excludes force carrying particles
- All particles can be classified according to the type of interaction they have with other particles



① Particles that interact through all 4 fundamental forces
- Protons + Neutrons are hadrons

② Particles that interact through 3 of the fundamental forces - excluding the Nuclear Strong F_s
- mass is $< m_{\text{proton}}$

③ A heavy particle in elementary particle theory can be transformed into a ${}^1_0\text{P}$ or ${}^1_0\text{n}$ and some number of mesons and lighter particles

- A particle of intermediate mass

- e^- , e^+ and neutrinos are leptons
- e^+ (a positron) same as m_e but charge is $+1.6 \times 10^{-19}$
- a neutrino is a neutral particle with mass $\ll m_e$ and has forward momentum

Charges of the 3 quarks must add to 0, +1, -1.

see quarks next lesson

- See Chart particles of the Standard Model
6 - leptons

An antiparticle is associated with each particle

- mass
- lifetime
- spin } Same for particles and antiparticles

- sign } opposite for charged particles and antiparticles

- magnetic moment } reversed in sign between particles and antiparticles

example ν = neutrino } pair
 $\bar{\nu}$ = anti-neutrino } pair

P = Proton } pair
 \bar{P} = anti-proton } pair

e^- particle } pair
 e^+ antiparticle } pair

Particles of the Standard Model

← current model a theory!

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Quarks - one of the basic particles having charges $\pm \frac{1}{3}e$ or $\pm \frac{2}{3}e$
 - make up elementary particles
 - Never found Separately.

Notice the charges -
 the e^- do not have the smallest charge.

Protons uud Neutron ddu

Name	up	charm	top
Symbol	u	c	t
Charge	$+\frac{2}{3}e$	$+\frac{2}{3}e$	$+\frac{2}{3}e$
	down	strange	bottom
	d	s	b
	$-\frac{1}{3}e$	$-\frac{1}{3}e$	$-\frac{1}{3}e$

Leptons

electron	muon	tau
e	μ	τ
$-1e$	$-1e$	$-1e$
electron neutrino	muon neutrino	tau neutrino
ν_e	ν_μ	ν_τ
0	0	0

Note: For each particle there is a corresponding antiparticle with a charge opposite that of its associated particle. Each generation More MASS/less

Generation 1 - everyday world only these quarks and leptons are observed

HEREBOOK

Dot 2

* The Std Model is a theory (not a law), that is used to explain the existence of all particles that have been observed and the forces that hold atoms together or lead to their decay.

FUNDAMENTAL FORCES in Nature

- Electromagnetic Force
- Weak Force
- Strong Force
- Gravitational Force

GUT's
 Grand Unification Theory
 - an attempt to combine these 3 forces

TOE's
 Theory of Everything
 an attempt to combine all 4 fundamental forces.
 - solving Dark Matter