

QUARK MODEL

(QUARKS : ULTIMATE CONSTITUENTS OF HADRONS)

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REQUIREMENT & PREREQUISITE

“Oh young man if I could remember the name of all those particles, I would have been a botanist” Fermi to Lederman

Existence of some more elementary particle need to explain :

I. Fitting of hadrons into 8-fold way

II. Redundancy of strongly interacting particles

III. Their isospin invariance

Gell-Mann and Zewig independently proposed that *all hadrons are composed of even more elementary constituents* (Gell-Mann them *Quarks* and Zewig called *Aces*)

These elementary particles should have :

- ❖ *Spin $\frac{1}{2}$, otherwise it would be impossible to construct spin $\frac{1}{2}$ or spin $\frac{3}{2}$ objects, e.g. nucleons*
- ❖ *Non-vanishing and fractional Baryon No.*
- ❖ *Non-vanishing and fractional electric charge (some with $-ve$ and other with $+ve$)*

THE MODEL

For Baryons

- They are found in either $\frac{1}{2}$ spin or $\frac{3}{2}$ spin (in units of \hbar)
- So we require 3 quarks to form a baryon and 3 antiquark to form antibaryons.
- Some of them are one type and other of another type

For Mesons

- ❖ They have either zero spin or integral spin.
- ❖ So they are composed of 2 quarks
- ❖ They have a pair of quark and an antiquark

Incorporating Strangeness

- ✓ The members of each isospin multiplet have essentially similar central mass.
- ✓ But the state of different strangeness differ considerably in mass.
- ✓ Mass difference of each increment of strangeness is roughly the same which couldn't just be an accident.
- ✓ So we require a quark responsible for Strangeness

QUARK FLAVOURS

- Quarks should have baryon no. $1/3$ and antiquarks to have baryon no. $-1/3$
- Initially there were three flavours of quarks
 1. up(u) with isospin $I = 1/2$; $I_3 = 1/2$; charge(Q) = $2/3$
 2. down(d) with isospin $I = 1/2$; $I_3 = -1/2$; charge(Q) = $-1/3$
 3. strange(s) with strangeness (S) = -1 ; charge (Q) = $-1/3$

As per Standard Model Of Particle Physics, there are six quark flavours and all these have been varied in experiments

	Flavours	Charge (Q)	Strangeness (S)	Charmness (C)	Bottomness (B)	Topness (T)
1 st Generation	up	$2/3$	0	0	0	0
	down	$-1/3$	0	0	0	0
2 nd Generation	strange	$-1/3$	-1	0	0	0
	charm	$2/3$	0	1	0	0
3 rd Generation	bottom	$-1/3$	0	0	-1	0
	top	$2/3$	0	0	0	1

QUARK COMBINATIONS

MESONS

Spin 0	Spin 1	Charge	Strangeness	Quark content
π^+	ρ^+	+1	0	$u\bar{d}$
π^0	ρ^0	0	0	$u\bar{u}, d\bar{d}, (1/2)^{1/2} (u\bar{u}-d\bar{d})$
π^-	ρ^-	-1	0	$\bar{u}d$
K^+	K^{*+}	+1	+1	$u\bar{s}$
K^0	K^{*0}	0	+1	$d\bar{s}$
K^-	K^{*-}	-1	-1	$\bar{u}s$
\bar{K}^0	\bar{K}^{*0}	0	-1	$\bar{d}s$
η		0	0	$(u\bar{u} + d\bar{d} - 2s\bar{s})/(6)^{1/2}$
	ω	0	0	$(1/2)^{1/2} (u\bar{u} + d\bar{d})$
	φ	0	0	$s\bar{s}$

QUARK COMBINATIONS

Baryons octet (spin 1/2)

Particle	Charge	Strangeness	Quark Content
p	+1	0	uud
n	0	0	udd
Λ^0	0	-1	uds
Σ^+	+1	-1	uus
Σ^0	0	-1	uds
Σ^-	-1	-1	$d\bar{d}s$
Ξ^0	0	-2	uss
Ξ^-	-1	-2	dss

Baryons Resonances decuplet (spin 3/2)

Particle	Charge	Strangeness	Quark Content
Δ^{++}	+2	0	uuu
Δ^+	+1	0	uud
Δ^0	0	0	udd
Δ^-	-1	0	ddd
Σ^{*+}	+1	-1	uus
Σ^{*0}	-1	-1	uds
Σ^{*-}	-1	-1	$d\bar{d}s$
Ξ^{*0}	0	-2	uss
Ξ^{*-}	-1	-2	dss
Ω^-	-1	-3	sss

Bibliography

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- 3). *Quarks* by Fritzsch H.
- 4). *Introduction to High Energy Physics* by Perkins D.H.