Quark Theory

Quark Theory: -

Gell Mann and George Zweing tentatively put forth the idea of quark theory in 1964. A Quark is an elementary particle a fundamental constituent of matter.

The elementary particles can be conceived (as far as isospin and hypercharge are concerned) as being built out of combinations of quarks. The quarks (a, b, c) are the basic state, which are represented as the basic three component column matrices.

$$a = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \qquad b = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \qquad c = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

The quarks a and b from an isospin doublet with T=1/2 and T_3=1/2 and -1/2, whereas the c quark is an isosinglet with T_3=0. The quarks can be interchanged with the unitary matrix, as

$$q_l = \sum_{j=1}^{3} U_{lj}\, q_j$$

The unitary matrices U can be expressed in terms of Hermitian generators F_j as

$$U = exp\left[i \sum_{j=1}^{8} \alpha_l F_j \right]$$

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Where α_1, α_2, ...α_8 are parameters and F_1, F_2 ..... F_8 are eight independent traceless hermitian 3×3 matrices. The quantum numbers of the quarks are given in the table

Quark	Q	T	T_3	B	Y	S
a	+2/3	½	1/3	1/3	1/3	0
b	-1/3	½	-1/2	1/3	1/3	0
c	-1/3	0	0	1/3	-2/3	-1

For the corresponding anti-quarks, the numerical values are the same but the same but the signs of Q, B, T_3, Y and S are changed. The anti-quarks are represented as row matrices

a = (1, 0, 0) **b** = (0, 1, 0) **c** = (0, 0, 1)

which transforms as

$$q_i = \sum q_i (U^+)_{ij}$$

In associating particles with SU(3) representation, the baryons with integer baryon number must be associated with states formed from three quarks. Thus for baryons a×b×c indicates 27 states (a singlet, two octets and a decuplet). The mesons with zero baryon number must be form one quark and one anti-quark. Thus for mesons a×b gives 9 state (a single and an octet). Examples of meson formation are as follows:

π^+ (ab), π^0 (aa), π^- (ab), K^+ (ac), K^0 (bc), K^- (ac), etc.

The quarks and anti-quarks are assumed to be the interacting particles of spin 1/2 carrying the quantum numbers shown in table. The fact that the quarks have not been detected in nuclear collisions, either in cosmic radiation or in high energy laboratories, suggested that the quark must have very high mass. The quarks have no independent existence outside the hadrons

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like the phonons of solid state physics. If the mesons are composed of one quark interacting with one anti-quark through a scalar potential, the total spin must be either 1 or 0. For the angular momentum L, the total spin P of the meson must be $(-1)^{2+1}$. The baryon states formed from three quarks must have total spin 3/2 or 1/2.

It has been suggested that meteorites might have collected quarks during their lifetimes in the planetary system of 4.5×10^{9} years. There are 6 types of quarks known as

1) up quark (u), 2) down quark (d), 3) strange quark (s), 4) charm quark (c), 5) bottom quark (b), 6) Top quark (t). Quarks have various intrinsic properties including electric charge, color charge, mass and spin.

Particle		Mass	J	B	Q(e)	T_3	C	S	T	B	Antiparticle	
Name	Symbol	(MeV/c^2)									Name	Symbol
up	u	1.7 – 3.1	1/2	+1/3	+2/3	+1/2	0	0	0	0	Antiup	u
down	d	4.1 – 5.7	1/2	+1/3	-1/3	-1/2	0	0	0	0	Antidown	d
charm	c	1275±25	1/2	+1/3	+2/3	0	+1	0	0	0	Anticharm	c
strange	s	95±5	1/2	+1/3	-1/3	0	0	-1	0	0	Antistrange	s
top	t	173210±510±710	1/2	+1/3	+2/3	0	0	0	+1	0	Antitop	t
bottom	b	4180±30	1/2	+1/3	-1/3	0	0	0	0	-1	Antibottom	b

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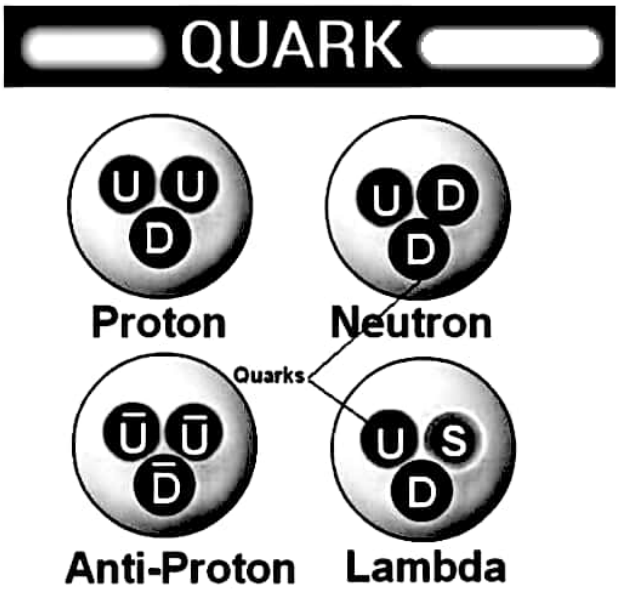
Summary of the quark theory: -

Quark is a fundamental constituent of matter and is defined as an elementary particle. These quarks combine to produce composite particles called ***hadrons***, the most stable of which are neutrons and protons that are the components of atomic nuclei. We can define quark as:



A quark is a type of elementary particle and a fundamental constituent of matter.

Theorized:	**George Zweig (1964); Murray Gell-Mann (1964)**
Types:	6 (up, down, strange, charm, bottom, and top)
Spin:	1/2
Baryon number:	1/3
Symbol:	Q

Types of Quarks: The six types are namely:

Up Quark

Up quarks are the lightest among all the quarks. They have maximum stability due to the lowest mass.

- The symbol used is U, and its antiparticle is denoted by $\bar{U}$.
- The mass of Up quark ranges from 1.7 – 3.1 MeV / c^2.
- Its electronic charge is 2/3 e.

Down Quark

The down quark comes next to up quarks regarding its light mass. Therefore, it also has high stability.

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- Down quark is denoted by d, and its antiparticle is denoted by $\bar{d}$.
- The mass of down quark ranges from 4.1 – 5.7 MeV / c^2.
- Its electric charge is -1/3 e.

The Strange Quark

The strange quark comes under third lightest among all.

- Strange quark is denoted by S, and its antiparticle is denoted by $\bar{S}$.
- Its electric charge is -1/3 e.

The Charm Quark

The meson which is called a J/Psi particle is an example of the charm quark.

- Charm Quark is denoted by C, and its antiparticle is denoted by $\bar{C}$.
- The electric charge is a quark of +2/3.

The Top Quark

The Top quark is denoted by t and its antiparticle is denoted by $\bar{t}$.

- The mass of top quark is 172.9 + 1.5 GeV/c2.
- Its electric charge is +2/3.

The Bottom Quark

The bottom quark is symbolized by b and its antiparticle is denoted by $\bar{b}$.

- The mass of bottom quark is approximately 4.1 GeV/c2.
- Its electric charge is -1/3 e.
- To know more about Quark and any physics-related concept.

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