CHAPTER - 4

FUNDAMENTAL BUILDING BLOCKS OF MATTER : PREONS

4.1 Preon Hypothesis

The need for preon hypothesis[11] will be clear, if we trace a similarity with the quark hypothesis. In hadron physics which consists of the study of a very large number of elementary particles including the nucleons, mesons and hyperons, a great economy was acheived when Gell-Mann and Zweig intoduced the concept of quarks. Thus quarks were proposed to be the basic constituents and the mesons and baryons were said to be $q\bar{q}$ and qqq composite states of them. A fundamental triplet of quarks; u,d,s could elegantly describe most of the properties of hadrons known at that time. The u and d were isospin doublet whereas the ^{s} quark was a strangeness singlet. Subsequently after discovery of charmed mesons a new flavour viz. charm (C) was added and a new quark c was introduced. Again the spin statistics problem needed that the quarks come into different colours RYB. Thus a colour symmetry was introduced. The colour symmetry could also explain quark confinement. But now, the number of fundamental constituents has gone to 4 x 3 = 12 After inclusion of new flavours b and ^{t} the number of quarks goes to 6 x 3 = 18. And if we postulate grand unification along with horizontal symmetry between the three generations of quarks and leptons we have six more leptons added to the above 18 quarks. Thus the total number of fundamental constituents becomes 24 which is quiet large. An economy can be introduced by postulating that the quarks and leptons are composite themselves. Thus each quark and lepton constitutes particles fundamental at this level, called as preons. We shall discuss two principle models of the preons : one which was put forward for the first

time historically: the Pati-Salam model, and the other, the rishon model of Harari and Sharpe.[12,13]

4.2 Pati-Salam Model[11]

This model consists of three types of preons.

(1) The Q quartet (Q = (P,n,λ χ) .

This carries the usual SU(3) quantum numbers and charm.

(2) The other is the colour quartet ℭ = abcd carrying the quantum numbers of $SU(3)_{colour}$ and lepton number.

(3) A neutral fermion S. It helps to render the quarks and leptons fermionic and three body composites $q\bar{c}s$.

A modern version of this model will possibly be a valency sextet Q = Pn λ χbt, coloured quartet C= abcd and S.

4.3 Rishon Model of H.Harari[12]

Rishin is the Hebrew word for primary. In the rishon model, it is assumed that each quark or lepton is a three-body composite of two types of preons or prequarks known as rishons. The two rishons denoted by T and V, are both fermions. The T rishon carries an electric charge Q = 1/3, whereas the V rishon is electrically neutral. Antirishons are also postulated. In this model the Ts and $\bar{V}$s can have any of the three colour charges (R,G,B) and the Vs and $\bar{T}$s take any of the three anti-colours ($\bar{R}$,$\bar{G}$,$\bar{B}$). (Table 4.1)

Table 4.1 Charges on the Rishon

Preon	Electric Charge	Colour Charge
Rishon T	1/3	R, G or B.
Rishon V	0	$\bar{R}$, $\bar{G}$ or $\bar{B}$.
Antirishon $\bar{T}$	-1/3	$\bar{R}$, $\bar{G}$ or $\bar{B}$.
Antirishon $\bar{V}$	0	R,G or B.

We can construct the first generation quarks and leptons from three rishons or antirishons as shown in Table 4.2.

Table 4.2 Rishon Model of First Generation Standard Model Constituents

First Generation Composite Particle	Rishon Content				
	Prequarks	Electric charge		Colour charge	
		on Prequarks	net	on Prequarks	net
e^-	$\bar{T},\bar{T},\bar{T}$	-1/3,-1/3 -1/3.	-1	$\bar{R},\bar{G},\bar{B}$	white
$\bar{u}$	$\bar{T},\bar{T},V$	-1/3,-1/3, 0.	-2/3	$\bar{B}\ \bar{R}\ R$ or $\bar{B}\ \bar{G}\ G$	$\bar{B}$
				$\bar{G}\ \bar{B}\ B$ or $\bar{G}\ \bar{R}\ R$	$\bar{G}$
				$\bar{R}\ \bar{B}\ B$ or $\bar{R}\ \bar{G}\ G$	$\bar{R}$
d	$\bar{T},\bar{V},\bar{V}$	-1/3,0,0	-1/3	as for u	B G or R
ν_e	$\bar{V},\bar{V},\bar{V}$	0,0,0	0	R,G,B	white
e^+	T,T,T	1/3,1/3,1/3	+1	R,G,B	white
u	T,T,V	1/3,1/3,0	+2/3	B,G,$\bar{G}$ or B,R,$\bar{R}$	B
				G,R,$\bar{R}$ or G,B,$\bar{B}$	G
				R,G,$\bar{G}$ or R,B,$\bar{B}$	R
$\bar{d}$	T,V,V	1/3,0,0	1/3	as for u	B,G or R
$\bar{\nu}_e$	V,V,V	0,0,0	0	$\bar{B},\bar{G},\bar{R}$	white

Salient Features of the Model

(1) We have only two basic particles with their antiparticles.

(2) All integrally charged particles are colour-singlets whereas all fractionally charged particles are coloured.

(3) This model explains equality of the magnitude of electric charge on an electron and proton as arising from same constituent preons.

4.4 Rishon Model of Rajput and Samuel[14]

This model treats quarks and leptons as four body composites. It consists of an additional neutral scalar rishon S and its antirishon $\bar{S}$. The placing of S will determine the generation of the composite particle, whereas the order of fermionic rishons T and V will determine its colour. The preons do not have any orbital angular momentum. The ground state of the composite can either have spin 1/2 or spin 3/2. It is further assumed that binding of the rishons is such that only the spin-1/2 states are lowest in mass.

The properties of the rishons in this scheme are shown in Table 4.3.

Table 4.3 Properties of preons in Rajput-Samuel Model

Preon	Electric charge	Angular Momentum
S	Arbitrary	0
T	$1/3 - Q_S/3$	1/2
V	$-Q_S/3$	1/2

The charges are related by

$$Q_T - Q_V = 1/3.$$

We can form the composite particles of all three generations by varying the position of S. The structures of quarks and leptons of all three generations is given in Table 4.4.

Table 4.4 Rishon Structure of all quarks and leptons.

Composite Particle	Colour	Preon Structure	charges			
			B	R	Q	L
νe	white	SVVV	0	4	0	+1
e^+	white	STTT	0	4	1	-1
u_1	Red	STTV	1/3	4	2/3	0
u_2	Green	STVT	1/3	4	2/3	0
u_3	Blue	SVTT	1/3	4	2/3	0
$\bar{d}_1$	Red	STVV	-1/3	4	-1/3	0
$\bar{d}_2$	Green	SVTV	-1/3	4	-1/3	0
$\bar{d}_3$	Blue	SVVT	-1/3	4	-1/3	0
ν_μ	white	VSVV	0	4	0	1
μ^+	white	TSTT	0	4	1	-1
C_1	Red	TSTV	1/3	4	2/3	0
C_2	Green	TSVT	1/3	4	2/3	0
C_3	Blue	VSTT	1/3	4	2/3	0
$\bar{S}_1$	Red	TSVV	-1/3	4	-1/3	0
$\bar{S}_2$	Green	VSTV	-1/3	4	-1/3	0
$\bar{S}_3$	Blue	VSVT	-1/3	4	-1/3	0
ν_τ	white	VVSV	0	4	0	1
τ^+	white	TTST	0	4	1	-1
t_1	Red	TTSV	1/3	4	2/3	0
t_2	Green	TVST	1/3	4	2/3	0
t_3	Blue	VTST	1/3	4	2/3	0

Composite Particle	Colour	Preon Structure	Charges			
			B	R	Q	L
$\bar{b}_1$	Red	TVST	-1/3	4	-1/3	0
$\bar{b}_2$	Green	VTSV	-1/3	4	-1/3	0
$\bar{b}_3$	Blue	VVST	-1/3	4	-1/3	0

The antiquarks and antileptons will have structural & charge assignment opposite to the respective quarks & leptons above.

At present the existence of two fermion generations is very well established, and there is very strong evidence for the existence of the third one. This forces us to go beyond the simple two-generation model, and as far as some specific schemes [15], are concerned, the minimal candidate is $[\ SU(2)_L \times U(1)]_{WS} \times U(1)$.

In other words for such schemes the existence of the third generation necessitates the coexistence of the fourth one as well [15]. The Rishon model of Rajpoot and Samuel is also seen to conform with the possibility of existence of fourth generation.

<u>The τ' family</u>

$\nu_{\tau'} = VVVS, \qquad \bar{\nu}_{\tau'} = \overline{VVVS}$

$\tau'^{+} = TTTS, \qquad \tau'^{-} = \overline{TTTS}$

$t'_1 = TTVS, \qquad t'_2 = TVTS \qquad t'_3 = VTTS.$

$\bar{t}'_1 = \overline{TTVS} \qquad \bar{t}'_2 = \overline{TVTS}, \qquad \bar{t}'_3 = \overline{VTTS}$

$\bar{b}'_1 = TVVS, \qquad \bar{b}'_2 = VTVS, \qquad \bar{b}'_3 = VVTS$

$b'_1 = \overline{TVVS} \qquad b'_2 = \overline{VTVS}, \qquad b'_3 = \overline{VVTS}$

Salient Features of the Model

(1) The electric charges of quarks and leptons for each generation are simply the sum of electric chrges of S, T and V rishons.

e.g. from the structure of the positron and its antineutrino we can write,

$$3\,Q_T + Q_S = 1$$

$$3\,Q_V + Q_S = 0$$

From this we get,

$$Q_T - Q_V = 1/3$$

Substituting this relation in the above equations we can express the electric charges of S,T,V rishons in terms of Q_S;

$$3(Q_V + 1/3) + Q_S = 1$$

$$\therefore\ 3Q_V + 1 + Q_S = 1$$

$$\therefore\ Q_V = -Q_S/3$$

and

$$3(Q_T - 1/3) + Q_S = 0$$

$$\therefore\ 3Q_T - 1 + Q_S = 0$$

$$\therefore\ Q_T = -Q_S/3 + 1/3$$

This shows that the charges of the rishons are not fixed. They depend on our choice for the value of Q_S. Thus, the total charge Q can be expressed as,

$$Q = (1/3 - Q_S/3)\ (n_T - n_{\bar{T}}) - Q_S/3(n_V - n_{\bar{V}}) + Q_S(n_S - n_{\bar{S}}).$$

(2) In addition to this, there are two more additive quantum numbers.

The Baryon number - Lepton number.

$$\therefore\ (B - L) = 1/3(n_T - n_{\bar{T}}) - 1/3\ (n_V - n_{\bar{V}})$$

and the rishon number which is,

$$R = (n_T - n_{\bar{T}}) + (n_V - n_{\bar{V}}) + (n_S - n_{\bar{S}})$$

(3) We can incorporate the various interactions in nature as gauge interactions by introducing gauge bosons. The gauge bosons can be either elementary or composite. We assume gauge bosons to be eight body composites.

e.g. $W^+ = STTTSVVV$

$W^- = \overline{STTTSVVV}$

The mediators of strong interactions viz. gluons can be expressed as follows.

e.g. $G_{12} = (STTV\ \overline{STVT}) + (STVV\ \overline{SVTV})$

Further we have following gauge bosons expressed in a similar way as above : the neutral vector boson Z^o, the photon γ , the vector bosons of horizontal interactions $F_{\alpha\beta}$, the leptoquarks X and Y.

(4) The position of S determines the generation, hence this scheme allows four possible generations.

(5) Order of T and V rishons determine the colour.

We emphasize that the preon models are meaningful only as static models and not dynamic once, since certain problems regarding the masses and confinement of the preons are not fully explained.

We can study and discuss various interactions of elementary particles-within the scheme. This will form the subject matter of the next chapter.

To see a World in a Grain of Sand
And a Heaven in a Wild Flower,
Hold Infinity in the palm of your hand
And Eternity in an hour.

WILLIAM BLAKE,
Auguries of Innocence.