On a Composite Model for the New Particles*

Shoichi Sakata

Institute for Theoretical Physics, Nagoya University, Nagoya

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Recently, Nishijima-Gell-Mann's rule[1] for the systematization of new particles has achieved a great success to account for various facts obtained from the experiments with cosmic rays and with high energy accelerators. Nevertheless, it would be desirable from the theoretical standpoint

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A note on the same supject has also been published in Bulletin de L'acadèmie Polonaise des Sciences (Cl, III-vol. IV, No. 6, 1956) to find out a more profound meaning hidden behind this rule. The purpose of this work is concerned with this point.

It seems to me that the present state of the theory of new particles is very similar to that of the atomic nuclei 25 years ago. At that time, we had known a beautiful relation between the spin and the mass number of the atomic nuclei. Namely, the spin of the nucleus is always integer if the mass number is even, whereas the former is always half integer if the latter is odd. But unfortunately we could not understand the profound meaning for this even-odd rule. This fact together with other mysterious properties of the atomic nuclei, for instance the beta disintegration in which the conservation of energy seemd to be invalid, led us to a very pessimistic view-point that the quantum theory would not be applicable in the domain of the atomic nucleus. However the situation was entirely changed after the discovery of the neutron. Iwanenko and Heisenberg[2] proposed immediately a new model for the atomic nuclei in which neutrons and protons are considered to be their constituents. By assuming that the neutron has the spin of one half, they explained the even-odd rule for the spins of atomic nuclei as the result of the addition law for the angular momenta of the constituents. Moreover, they could reduce all the mysterious properties of atomic nuclei to those of the neutron contained in them.

Supposing that the similar situation is realized at present, I proposed a compound hypothesis for new unstable particles to account for Nishijima-Gell-Mann's rule. In our model, the new particles are considered to be composed of four kinds of fundamental particles in the true sense, that is, nucleon, antinucleon, Λ^0 and anti-Λ^0. If we assume that Λ^0 has such intrinsic properties as were assigned by Nishijima and Gell-Mann, we can easily get their even-odd rule for the composite particles as the result of the addition laws for the ordinary spin, the isotopic spin and the strangeness. In the next table, the models and the properties of the new particles are shown together with those of the fundamental particles in the true sense.

Name	Model	Isotopic Spin	Strangeness	Ordinary Spin
$\mathfrak{N}$		1/2	0	1/2
$\bar{\mathfrak{N}}$		1/2	0	1/2
Λ		0	-1	1/2?
$\bar{\Lambda}$		0	1	1/2?
π	$\mathfrak{N}+\bar{\mathfrak{N}}$	1	0	0
$\theta(\tau)$	$\mathfrak{N}+\bar{\Lambda}$	1/2	1	0?
$\bar{\theta}(\bar{\tau})$	$\bar{\mathfrak{N}}+\Lambda$	1/2	-1	0?
Σ	$\mathfrak{N}+\bar{\mathfrak{N}}+\Lambda$	1	-1	1/2?
Ξ	$\bar{\mathfrak{N}}+\Lambda+\Lambda$	1/2	-2	1/2?

Here $\mathfrak{N}$ and $\bar{\mathfrak{N}}$ denote nucleon and antinucleon respectively, whereas Λ and $\bar{\Lambda}$ denote Λ^0 and anti-Λ^0 respectively[3].

So far as the internal structure is not concerned, our model for new particles is identical with that of Nishijima and Gell-

Mann. However, it should be stressed that the curious properties of the new particles could be reduced to those of Λ^0, just like the mysterious properties of the atomic nuclei were reduced to those of neutron. Hence our theory contains less arbitrary elements than was the case for original one of Nishijima and Gell-Mann.

Though the rigorous treatment of our model is a very hard task[4], it is worthwhile to notice that most of the composite particles which seem to be stable against the strong interaction can be identified with the well-known new particles, and that there are possibilities of predicting some more new particles which have not been discovered up till now.[5]

Finally, it should be remarked that there are some other arguments in favour of the compound hypothesis for the elementary particles. In spite of the great success achieved by the advent of Tomonaga-Schwinger's technique, it has recently become clear that we could not avoid the internal inconsistency of the quantum field theory, so far as the point model for elementary particles was adopted. Moreover, in the case of π-meson, the cut-off prescription has recently been proved to be very powerful in order to account for the experimental results. These facts indicate strongly the necessity of substantial innovations in the model for the elementary particles, though some change has already been made by the discovery of the renormalization technique. Landau pointed out that the model for the electron would possibly be changed by the effect of the gravitational field. But in the case of π-meson we must look for another effect, because the cut-off radius is found to be as large as the order of the nucleon Compton wave length in contrast to $e^2/mc^2 \cdot e^{-137} \sim 10^{-58}$ cm which appeared in the quantum electrodynamics.[6]

1) T. Nakano and K. Nishijima, Prog. Theor. Phys. **10** (1953), 581; K. Nishijima, Prog. Theor. Phys. **12** (1954), 107; **13** (1955), 285; M. Gell-Mann, Phys. Rev. **92** (1953), 833.
2) D. Iwanenko, Nature **129** (1932), 798; W. Heisenberg, ZS. Phys. **77** (1932), 1.
3) Markov (Rep. Acad. Sci. USSR, 1955) proposed also a composite model which is very similar to ours. It should be remarked that our model may be considered as a generalization of the π-meson model proposed by Fermi and Yang (Phys. Rev. **76** (1948), 1739), and that it will throw a new light on Heisenberg's theory of elementary particles (Zs. Naturf. **9a** (1954), 291; **10a** (1955), 425), in which only one kind of "Urmaterie" is assumed.
4) S. Tanaka, Prog. Theor. Phys. **16** (1956), 625. Z. Maki, Prog. Theor. Phys. **16** (1956), 667.
5) K. Matsumoto, Prog. Theor. Phys. **16** (1956), 583.
6) M. A. Markov, Uspekhi Fiz. Nauk **51** (1953), 317; L. Landau et al., DAN. **95** (1954), 497, 733, 1177; **96** (1954), 261; **102** (1955), 489; S. Kamefuchi & H. Umezawa, Prog. Theor. Phys. **15** (1956), 298; Nuovo Cimento **3** (1956), 1060.