It is easy to see that the new "strangeness" quantum number introduced be Gell-Mann can now be interpreted as the meson charge of the K and Ξ particles which is responsible for the interaction between these particles. In contrast with electric charge, the quanta of the meson-charge field are π-mesons and this change is not conserved in weak interactions occuring 10^{12} times slower than nuclear interactions. As slower than nuclear interactions. As a consequence we have the spontaneous transformation of hyperons into nucleons according to the following scheme:

$$Y \underset{\text{(fast)}}{\rightleftarrows} (Y + \pi + \pi + \ldots) \underset{\text{(slow)}}{\rightleftarrows} (Y + K) \underset{\text{(fast)}}{\longrightarrow} N + \pi.$$

We now consider nucleon disintegration on the basis of the structural schemes in (3) and (4). The disintegration can occur as a result of the absorption of the incident π-meson by a K-meson or Ξ-particle. In the first case the K-meson angular distribution [which we denote by $f_1(\theta)$] should be highly peaked in the forward direction. In the case in which the π-meson is absorbed by the Ξ-particle, the K-meson angular distribution [which we designate by $f_2(\theta)$] should be approximately isotropic with some predominance of the K-mesons emitted in the backward direction.[1] The table lists various nucleon disintegration reactions produced by the absorption of a π-meson. To find the relative weights to be assigned to the ratio of the cross sections for the various reactions we have assumed that the absorption of the π-meson is equally probable in K and Ξ particles.

Reaction	Particle which absorbs the π-meson	Weight for the reaction	Angular distribution
$\pi^- + p \to K^0 + \Lambda^0;\ \Sigma^0$	K^+ or Ξ^0	$3 + 1/2 = 7/2$	$6f_1 + f_2$
$\pi^- + p \to K^+ + \Sigma^-$	Ξ^0	$1/2$	f_2
$\pi^+ + n \to K^+ + \Lambda^0;\ \Sigma^0$	K^0 or Ξ^-	$3 + 1/2 = 7/2$	$6f_1 + f_2$
$\pi^+ + n \to K^0 + \Sigma^+$	Ξ^-	$1/2$	f_2
$\pi^- + n \to K^0 + \Sigma^-$	K^+ or Ξ^0	$1+1=2$	$f_1 + f_2$
$\pi^+ + p \to K^+ + \Sigma^+$	K^0 or Ξ^-	$1+1=2$	$f_1 + f_2$

In work with a beam of 1.3-Bev negative pions it has actually been observed that the K^0-particles produced in the reaction ($\pi^- + p \to K^0 + \Lambda^0;\ \Sigma^0$) exhibit a highly pronounced asymmetry in the forward direction in the center-of-mass system while the angular distribution of the K^+-particles produced in the reaction $\pi^- + p \to K^+ + \Sigma^-$ is relatively isotropic with some predominance in the backward direction.[2]

The system which we have formulated is absolutely stable against decay into light particles if the Ξ-particle is absolutely stable against the analogous process. It is known that the nucleon lifetime is greater than 10^{22} years.[3] From this estimate we can conclude that the lifetime of the Ξ-particle can not be less than 10^8 years since nucleon decay can occur only if the Ξ-particle decay coincides with the decay of one of the K-mesons. The probability of this event is approximately 10^{14} times smaller than the probability of decay of a Ξ-particle. If the Ξ-particle is not the bare core of the nucleon but is itself a system consisting of a heavy hyperon, in whose π-meson field we find n K-mesons, this hyperon can undergo in the free state comparatively rapid decay into light particles. Thus we arrive at the conclusion that the law of conservation of the number of baryons, formulated in the form of a conservation law for nuclear charge, may be completely invalid. In this case there is a possibility of liberating in individual collisions the total energy corresponding to the nucleon mass.

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POLAR THEORY OF METALS

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In the polar model of metals proposed by Vonsovskii one introduces a new parameter of the metal — the degree of polarization s, which can be defined as the ratio of the mean number of "pairs" or "holes" to the total number of valence electrons. In the final analysis the degree of polarization determines all the physical properties of the metal; as yet, however, the theory cannot give the magnitude of this quantity. We give below an estimate of the degree of polarization s, relating this quantity to fluctuations of the electron density in the metal.

We divide the entire metal into equal elementary polyhedra with centers at the interstices of the crystal lattice; let z be the valence of the metal atoms. Interpreting the degree of polarization as the probability of finding a given atom in the "hole" or "pair" state, the mean number and the mean square of the number of electrons in one polyhedron is given by

$$\overline{N} = s(z+1) + s(z-1) + (1-2s)z = z,$$
$$\overline{N^2} = s(z+1)^2 + s(z-1)^2 + (1-2s)z^2 = z^2 + 2s. \tag{1}$$

Whence, for the square of the fluctuation we obtain a value 2s, so that

$$s = {}^1/_2\overline{(\Delta N)^2}. \tag{2}$$

The degree of polarization of the metal is thus related in a simple way to fluctuations in the density of valence electrons in an elementary polyhedron.

The problem of finding $\overline{(\Delta N)^2}$ is in itself no easier than the problem of determining s directly; however, in the alkali metals we can estimate $\overline{(\Delta N)^2}$ by starting from the free-electron model, since this model is qualitatively valid in these metals. Thus we have[1]

$$\overline{(\Delta N)^2} = 1 + n\iint \nu(|\mathbf{r}_1 - \mathbf{r}_2|)\, dV_1\, dV_2, \tag{3}$$

where $\nu(r)$ is the electron correlation function, n is the mean electron density, and the integration is carried out twice over an elementary polyhedron. The calculations can be simplified by replacing the polyhedron by a sphere of radius $R = (3/4\pi n)^{1/3}$. The unity term in (3) is obtained by substituting N=1.

The correlation function for a completely degenerate ideal Fermi gas can be used for $\nu(r)$.[1]

$$\nu(r) = -\frac{1}{4\pi^4 nr^6}\left\{\sin\frac{p_0}{\hbar}r - \frac{p_0}{\hbar}r\cos\frac{p_0}{\hbar}r\right\}^2, \tag{4}$$

where $p_0 = \hbar(3\pi^2 n)^{1/3}$ is the limiting momentum of the Fermi distribution or, using the correlation function for a Fermi gas with allowance for the Coulomb interaction between electrons according to the Debye–Hükkel method,[1]

$$\nu(r) = -(\varkappa^2/4\pi)e^{-\varkappa r}/r, \quad \varkappa^2 = (4me^2/\hbar^2)(3n/\pi)^{1/3}. \tag{5}$$

It is assumed that the positive charge of the metal ions is uniformly distributed over the entire lattice.

In (4) it is apparent that the quantity n can be completely determined by calculation and by direct integration we find s = 0.4145. In (5), in the same way, we find[2]

$$s = \frac{1}{4}\left\{1 + \frac{3(x^2-1)}{2x^3} + \frac{3(x+1)^2}{2x^3}e^{-2x}\right\}, \tag{6}$$

where $x = (e/\hbar)(6m/\pi)^{1/2}n^{-1/6} = 2\times 10^4 n^{-1/6}$. In the alkali metals $x \sim 4$, so that Eq. (6) can be simplified considerably and

$$s = {}^1/_4 + 1{,}875\cdot 10^{-5}\cdot n^{1/6}. \tag{7}$$

With $n = 4\times 10^{22}$ we find s = 0.361. Thus, taking into account the electronic Coulomb interaction tends to reduce s.

Although both estimates are somewhat lower than the value s = 0.5 proposed by Vonsovskii for alkali metals,[3] they are both still too high. Taking account of the Coulomb interaction between the electrons and ions could reduce the magnitude of s still further; however, a calculation of this effect is impossible within the framework of the Debye–Hükkel approximation. (The calculation itself is not difficult but if one assumes point ions the effect becomes so large that $s < 0$.)

If we assume that the electron gas is not completely degenerate, we must introduce a temperature correction for s in the estimate given above. For example, in (5) we must replace the quantity κ everywhere by $\kappa\{1-(\pi^2/48)(kT/\mu)^2\}$ where μ is the limiting Fermi energy. A simple calculation leads to the expression

$$s(T) = s_0 + 2{,}63\cdot 10^{15}\cdot n^{-7/6}T^2. \tag{8}$$

where s_0 is the value of s given before in (7). With $n \sim 10^{22}$ the temperature effect is insignificant although, in principle, the degree of polarization should increase with increasing temperature.

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PROBABILITY FOR CHARGE EXCHANGE IN NUCLEONS WITH ENERGIES OF $3 \times 10^9 - 10^{10}$ ev IN INTERACTIONS WITH AIR NUCLEI

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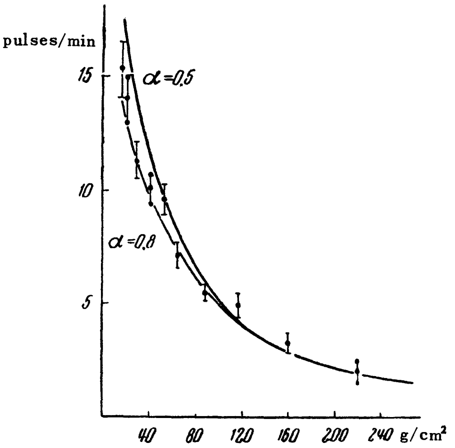
In the last several years a number of papers have been published in which the authors, investigating nuclear-cascade showers in cosmic rays, have reached the conclusion that in the interaction of high-energy nucleons (several Bev and higher) with air nuclei, the main part of the energy (about 70 percent) in the stars which are produced is carried off by one of the emitted nucleons, which in turn also produces stars.[1,2] It is of interest to examine the dependence of the charge of this nucleon on the charge of the incoming nucleon.



We shall assume that protons and neutrons with the energies in question ($3 \times 10^9 - 10^{10}$ ev) interact with air nuclei in the same way. We shall denote the probability of charge exchange for a high-energy nucleon in collision with an air nucleus by the quantity $1-\alpha$, i.e., α is the probability that the main energy of the star produced by the proton (neutron) is carried away by a nuclear-active proton (neutron). We neglect deviations from the direction of the primary nucleon. Then the cascade equations which describe the nucleon history can be solved rather simply if it is assumed that the nucleon energy spectra are independent of depth. The latter assumption is in satisfactory agreement with the experimental data obtained in investigations of high-energy cosmic rays.

Depth	$\alpha=0.5$	$\alpha=0.8$	Experiment
0.9	0.6	0.4	0.35 ± 0.1[4] 0.45 ± 0.2[6]
11	0.99	0.91	0.83 ± 0.1[5] 0.72 ± 0.15[6]

We denote the flux of primary particles incident on the boundaries of the atmosphere by $i_0(E)$. Then the dependence of the global proton flux $P(E, x)$ and neutron flux $N(E, x)$ on the depth x assumes the following form

$$P(E, x) = {}^1\!/_2\, i_0(E) [\mathscr{E}_1(\mu x) + \mathscr{E}_1(\eta x)], \quad N(E, x) = {}^1\!/_2\, i_0(E) [\mathscr{E}_1(\mu x) - \mathscr{E}_1(\eta x)]$$

(x is expressed in units of free path ≈ 60 g/cm^2) where $\eta = 1-(2\alpha-1)(1-\mu)$ and $\mathscr{E}_1$ is the Gol'dovskii integral. The absorption coefficient μ, found from numerous experiments, is approximately 60 g $\times$ cm^{-2}/120 g $\times$ cm^{-2} = 0.5. The presence of multiply-charged nuclei in primary cosmic radiation (chiefly He) tends to increase the number of protons and neutrons by an amount which is independent of α and equal to

$$\xi a i_0(E) [\mathscr{E}_1(\mu x) - \mathscr{E}_1(\xi x)] / (\xi - \mu),$$