threshold for K-particle pair-production is by itself sufficient to show the correctness of the particle-mixture theory.

The experimental arrangement[5], in which it was proposed to study the variation with time of the composition of a beam of θ^0-particles by observing the decay of the short-lived $\theta_1{}^0$ and Λ^0 components, requires the use of either a cloud-chamber or a bubble-chamber. Since K^--particles have a long life-time, they could be observed in our version of the experiment at a large distance from a suitably designed synchrophasotron target. The method of observing the K^--particles could then be the usual one (magnetic deflection and focussing) which was used for example in the experiments on the nuclear interactions of stopped K^--particles. This makes the experiment technically simpler.

In one possible arrangement of the experiment, the ratio (K^-/K^+) or (K^-/π^+) could be measured as a function of target size, using for example cylindrical targets with height and diameter equal. The (K^-/K^+) ratio, obtained from a proton beam of constant energy below the K^--particle "creation" threshold, should increase with the size of the target. In principle one could obtain from the experiment not only information about the $\theta_1{}^0$ and $\theta_2{}^0$ decay modes but also about the charge-exchange scattering process. One might expect that the upper limit of the (K^-/K^+) ratio at energies below the pair-creation threshold will be given by

$$(K^- / K^+) \leqslant {}^1/_4\, (\theta^0 / K^+)\cdot \delta_{opt} / \lambda\, (\tilde{\theta}^0 \to K^-),$$

Here (θ^0/K^+) is the ratio of the numbers of neutral and positive K-particles initially created, ¼ is the maximum number of $\tilde{\theta}^0$-particles which can arise from a single θ^0 by the Gell-Mann-Pais-Piccioni effect, δ_{opt} is the thickness of the target* in grams per cm^3, and $\lambda(\tilde{\theta}^0 \to K^-)$ is the mean free path for the charge-exchange process. The order of magnitude of the (K^-/K^+) ratio works out at about 0.01.

When a thick target is bombarded with protons above the K-particle pair threshold, the Gell-Mann-Pais-Piccioni effect may still markedly increase the flux of K^--particles. M. Podgoretskii has remarked that this may be important in designing experiments in which a high (K^-/π^-) ratio is required.

One may also find a relatively large probability for "charge exchange" of K^+-particles through two successive nuclear interactions $(K^+ \to \theta^0 \to \tilde{\theta}^0 \to k^-)$. When a beam of K^+-particles bombards a thick target, the ratio of the numbers of charged K-particles which are scattered with and without charge-exchange will be, as in the previous case, of the order of magnitude 0.01.

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* The thickness δ_{opt} ought to be less (by about a factor 3) than the absorption mean free path of the K^--particles.

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Nuclear Saturation and the Lévy–Klein Potential of Pseudoscalar Meson Theory

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THE question of nuclear saturation has been investigated[3,4] on the basis of two models of the nuclear forces[1,2] derived from pseudoscalar meson theory. The authors of Ref. 3 came to the conclusion that the Lévy potential,[1], which has a strong Wigner–type attraction produced by two–meson exchange, satisfies the requirements of nuclear saturation if one includes the repulsive three-particle force arising from pair terms. In Ref. 4 it was shown that the two–particle potential[2] derived from pseudoscalar meson theory with gradient coupling (and without pair terms), including single and double meson exchange, gives a satisfactory degree of saturation for heavy nuclei without considering three–particle repulsion, provided that one takes in account not only the repulsive core of radius r_c but also the weak repulsion in the odd P–states.

It was found earlier [5–8] that the second–order potentials of neutral pseudoscalar and scalar meson theory, supplemented by an ordinary repulsive force (independent of σ and τ), give the correct saturation at the binding energy and density of heavy nuclei. The present paper deals with the problem of nuclear stability, using the non–relativistic two–particle potential $V_{12} = V_2 + V_4^{(a)} + V_4^{(b)}$ of pseudoscalar meson theory, including terms of second and fourth order. Our result is that when the one–pair term $V_4^{(b)}$, which is a repulsive potential, is included in V_{12}, nuclear stability cannot be obtained even by bringing in three-particle repulsions. This contradicts the conclusions of Ref. 3.

In the non–relativistic approximation, the interaction potential between two nucleons, calculated in pseudoscalar charge–symmetric meson theory with pseudoscalar coupling, including effects of single and double meson exchange, has the form[3,9–13]

$$V_{12} = V_2 + V_4^{(a)} + V_4^{(b)}, \tag{1}$$

where

$$V_2 = \frac{1}{3}\frac{G^2}{4\pi}\left(\frac{\mu}{2M}\right)^2 (\tau_1\tau_2)\left\{\sigma_1\sigma_2 + S_{12}\left[1 + \frac{3}{\mu r} + \frac{3}{(\mu r)^2}\right]\right\}\frac{e^{-\mu r}}{r}, \tag{2}$$

$$V_4^{(a)} = -3\left(\frac{G^2}{4\pi}\right)^2\left(\frac{\mu}{2M}\right)^2 \frac{1}{\mu r^2}\frac{2}{\pi} K_1(2\mu r), \tag{3}$$

$$V_4^{(b)} = 6\left(\frac{G^2}{4\pi}\right)^2\left(\frac{\mu}{2M}\right)^3 \frac{1}{\mu r^2}\left(1 + \frac{1}{\mu r}\right)^2 e^{-2\mu r}. \tag{4}$$

Here S_{12} is the tensor force operator, K_1 is the first-order Hankel function, $r = |\mathbf{r}_1 - \mathbf{r}_2|$ is the distance between the nucleons, μ and M are the meson and nucleon masses, and $\hbar = c = 1$.

The strongly attractive potential $V_4^{(a)}$ is largely compensated by the repulsive potential $V_4^{(b)}$, and so the fourth-order interaction $V_4 = V_4^{(a)} + V_4^{(b)}$ produced by double meson exchange gives a weak attraction for intermediate values of r around $\mu r = 1$. This differs from the strong attraction $V_4^{(a)}$ which appears in the Lévy potential calculated by the Tamm–Dancoff method. Lévy made an error[9,13] in the calculation of V_{12}. The repulsive potential $V_4^{(b)}$, which was not included in our earlier analysis[1,3] of the properties of nuclei, will significantly change the results we obtained.

In this note we use the two–nucleon potential (1) supplemented by a repulsive core of radius r_c:

$$V_{12} = \begin{cases} V_2 + V_4^{(a)} + V_4^{(b)} & \text{for } r > r_c, \\ \infty & \text{for } r < r_c. \end{cases} \tag{5}$$

following the usual method[3,5–8] and assuming a uniform density of nuclear matter, we obtain expressions for the mean nuclear potential produced by the interaction (5):

$$\langle V_{12}\rangle = \langle V_2\rangle + \langle V_4^{(a)}\rangle + \langle V_4^{(b)}\rangle, \tag{6}$$

$$\langle V_2\rangle = -A\,\frac{9}{8}\,\mu\lambda\,\frac{\mu}{2M}\frac{1}{\eta^3}\int_b^\infty x e^{-x} D(\alpha x)\,dx, \tag{7}$$

$$\langle V_4^{(a)}\rangle = -A\,\frac{9}{\pi}\,\mu\lambda^2\frac{1}{\eta^3}\left[\frac{1}{2}K_0(2b) - \frac{1}{4}\int_b^\infty K_1(2x)\,D(\alpha x)\,dx\right], \tag{8}$$

$$\langle V_4^{(b)}\rangle = A\,9\mu\lambda^2\frac{\mu}{2M}\frac{1}{\eta^3}\left[\frac{b+2}{2b}e^{-2b} - \frac{1}{4}\int_b^\infty \left(1 + \frac{1}{x}\right)^2 e^{-2x} D(\alpha x)\,dx\right] \tag{9}$$

The notations are those of Ref. 3;

$$D(\alpha x) = [3j_1(\alpha x)/\alpha x]^2,$$

j_1 is the first-order spherical Bessel function, $R = \eta A^{1/3}\mu^{-1}$ is the nuclear radius, $(1/\mu) = 1.4 \times 10^{-13}$ cm is the meson Compton wave–length, $\alpha = 1.52/\eta$, $b = \mu r_c$, $\lambda = (G^2/4\pi)(\mu/2M)$, A is the nuclear mass number, and η is a parameter measuring the departure of the nuclear radius from its equilibrium value $R_s = A^{1/3}\mu$.

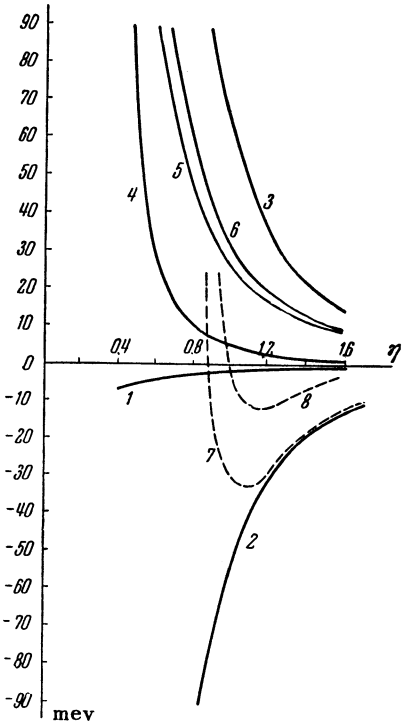
The kinetic energy of the nucleon gas, considered as a gas of hard spheres of radius r_c, is given[3] by

$$T = 14{,}7\,A\,(\eta^{-2} + 2.16\,b\eta^{-3})\ \text{MeV}. \tag{10}$$

The total energy of the nucleus is

$$E = \langle V_{12}\rangle + T. \tag{11}$$

a function of the parameters η, μ, λ.



1– $\langle V_2 \rangle / A$; 2– $\langle V_4^{(a)} \rangle / A$; 3– $\langle V_4^{(b)} \rangle / A$; 4 – $\langle V_{12} \rangle / A$; 5 – T/A; 6 – E/A; 7 – $\langle V \rangle / A = (\langle V_2 \rangle + \langle V_4^{(a)} \rangle + \langle V_{123} \rangle)/A$; 8 – $E/A = (\langle V \rangle + T)/A$. Curves 1–6 were computed by us, curves 7–8 taken from Ref. 3. All refer to $G^2/4\pi = 10$, $r_c = 0.38\ \hbar/\mu c$.

In the figure we show the potential, kinetic and total energy per nucleon as a function of η, assuming $G^2/4\pi = 10$, $r_c = 0.38\ (\hbar/\mu c)$. The curves show that the energies $(\langle V_{12} \rangle / A)$ and (E/A) are positive in the range $0.3 \leq \eta \leq 1.6$. The energy $\langle V_4^{(b)} \rangle$ due to two–particle repulsions completely cancels the attractive energy $\langle V_2 \rangle + \langle V_4^{(a)} \rangle$, and so the binding energy does not saturate at normal nuclear density ($\eta \sim 1$). The same behavior of (E/A) occurs also for $(G^2/4\pi) = 7.5, 5.2, 1$ and $r_c = 0.38\ (\hbar/\mu c)$. Thus it is not necessary, in considering the nuclear saturation problem with the potential (5) derived from pseudoscalar meson theory, to introduce the three–particle repulsion which adds a positive term $\langle V_{123} \rangle$ to the nuclear energy. This result contradicts our earlier statement[3] that the Lévy potential (without the $V_4^{(b)}$ term)

$$V_{12} = \begin{cases} V_2 + V_4^{(a)}, & r > r_c, \\ \infty & r < r_c, \end{cases}$$

supplemented by the three–particle repulsion, will produce saturation in heavy nuclei. Actually, the term $(\langle V_{123} \rangle / A)$ due to three–particle repulsions, in the absence of the $V_4^{(b)}$ term, just sufficiently weakens the strong attraction $(\langle V_{12} \rangle / A)$ so that the total energy per nucleon (E/A) has a minimum of –12 mev at normal nuclear density (η = 1– 1.5). Our calculation shows that the Lévy–Klein potential defined by Eq. (5) gives no nuclear saturation, either with or without the addition of a three–particle repulsion.

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The Problem of Parity Non-conservation in Weak Interactions

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ONE of the possible theoretical explanations of the paradox of the θ and τ–decay of K-mesons[1]