pion pole. At the threshold, this diagram describes interaction only with time-dependent quanta, which are not present in the photoproduction process.

It is interesting to note that the validity of the Kroll-Ruderman theorem is evident simply from the fact that all the transverse covariants, in terms of which the photoproduction amplitude is expressed [6], viz. $\gamma_5\sigma_{\mu\nu}k_\nu$, $\gamma_5[P_\mu(qk) - q_\mu(Pk)]$, $\gamma_5[\gamma_\mu(qk) - q_\mu\hat{k}]$, $2\gamma_5[\gamma_\mu(Pk) - P_\mu\hat{k}] - m\gamma_5\sigma_{\mu\nu}k_\nu$ ($P = (p + p')/2$) vanish when $k = 0$. Therefore a zero contribution will be made only by the pole diagrams containing the characteristic infrared factors $(pk)/2$ etc.

In conclusion we point out that the assumption that the functions $h(k^2)$ and $K(k^2)$ are slowly varying enables us to calculate the effective-pseudoscalar constant in μ capture. In this case the momentum transfer is equal to $k^2 = -0.52\,\mu^2$. The sought constant can be written in the form

$$g_P = g_A \frac{2mm_\mu}{k^2}\left[h(k^2) + \frac{\mu^2}{k^2 - \mu^2}\frac{K(k^2)}{K(0)}\right] \tag{6}$$

(m_μ is the muon mass). Putting again $h(k^2) \approx K(k^2)/K(0) \approx 1$, we obtain

$$g_P = -\,6.7 g_A. \tag{7}$$

Estimates leading to a similar result [7] are widely known. We wish to emphasize, however, that the obtained value is not merely of the correct order of magnitude. Allowance for the change in $K(k^2)$, with the aid of linear extrapolation ($K(0) = 0.87$, $K(\mu^2) = 1$), leads to a value $-7.5g_A$. Thus, the true value of g_P can hardly differ from (7) by more than 10 - 15%.

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SCATTERING OF KILOVOLT NEUTRONS BY LEAD AND ELECTRIC POLARIZABILITY OF THE NEUTRON

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Experimental determination of the nucleon-polarizability coefficients yields very useful information connected with the internal structure of the nucleon. Gol'danskii et al. [1] obtained for the proton electric polarizability coefficient a value $\alpha_p = (0.9 \pm 0.4) \times 10^{-42}$

cm^3. No measurement of the corresponding quantity α_n for the neutron has been made to date. This measurement is so difficult that one can speak for the time only of experimental estimates. Such estimates are given in several papers [2-6]. Until recently the best estimate was $\alpha_n < 20 \times 10^{-42}$ cm^3 [4], obtained as a result of an analysis of data on the scattering of neutrons with energies higher than 50 keV. Aleksandrov et al. [6] presented preliminary results on scattering by lead at lower neutron energies, down to 7.5 keV. They pointed out the possibility of greatly lowering the estimate obtained by Thaler [4]. In this note we present the results of similar more precise experiments.

The electric polarizability can be reflected in the scattering process by addition to the purely-nuclear interaction of an interaction between the electric dipole moment $\vec{p} = \alpha_n\vec{E}$ induced in the neutron and the Coulomb field $\vec{E}$ of the nucleus. The latter interaction is described by a potential of the type $\alpha_n Z^2e^2/2r^4$, where Z is the atomic number of the nucleus and e the electron charge. At reasonable values of α_n, the amplitude of the corresponding "polarization" scattering, calculated in the Born approximation [7], turns out to be much smaller than nuclear scattering, and the experiment consists of seeking for the interference between the "polarization" scattering and the nuclear potential scattering.

If we represent the differential scattering cross section in the form

$$\sigma(\vartheta) = \frac{\sigma_0}{4\pi}\left[1 + \sum_{\ell=1}^{\infty}\omega_\ell P_\ell(\cos\vartheta)\right], \tag{1}$$

where σ_0 is the total potential scattering cross section, and use the well known approximate relation for the phase of the scattering by the short-range potential of the nucleus

$$\delta_\ell \sim (kR)^{2\ell+1},$$

where k is the wave number of the neutron and R the radius of the nucleus, then we can readily verify that in the case of pure nuclear interaction the coefficient ω_1 is a linear function of the neutron energy E. When account is taken of the interference between the nuclear and "polarization" scattering, there appears in ω_1 a term proportional to k, so that

$$\omega_1 = aE + bE^{1/2}, \tag{2}$$

and for the constant b we obtain the expression

$$b \simeq -2.5 \times 10^{-4}\,\frac{m^{3/2}e^2}{\hbar^3}\,\frac{\alpha_n Z^2}{\sigma_0^{1/2}}, \tag{3}$$

if the energy E in (2) is expressed in keV (m is the neutron mass). The minus sign in (3) is a reflection of the fact that the real part of the nuclear-scattering amplitude is negative in the case under consideration.

Such an analysis was carried out for the scattering of 50 - 300 keV nuclei by uranium nuclei, and yielded the aforementioned estimate of α_n [4]. In our investigation, the scatterer was lead, which is preferred because it has no strong neutron resonances in the investigated energy range up to 26 keV, thus avoiding the ambiguity connected with neglecting the role of the resonances. The chosen energy region is also more convenient since the non-linear dependence of ω_1 on E (formula (2)) is much less pronounced in it.

The measurements were made with the JINR pulsed reactor [9] by the time-of-flight method with a 250 m base and with an energy resolution ranging from 20% at 1 keV to 100% at 26 keV. The effective energy was determined at each point by numerical integration with account of the resolution function, the neutron spectrum, and the energy sensitivity of the detectors. A total of 180 proportional boron counters (type SNMO-5) were used as detectors. The intensity of the neutrons scattered by a hollow lead cylinder of 10 cm diameter and 1 cm wall thickness was measured simultaneously at all energies and 9 values of the scattering angle from 30 to 150°.

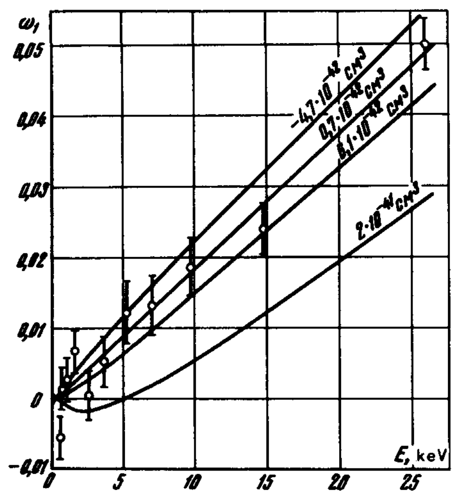

Fig. 1. Coefficients ω_1 for different neutron energies.

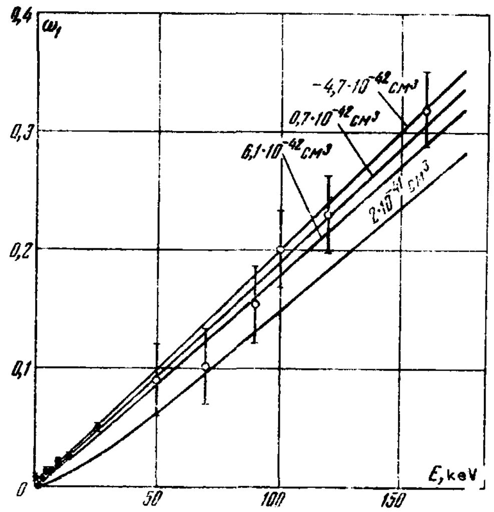

Fig.2. The same as Fig. 1. o - data obtained from the paper of Goldberg at al. [8], • - our data.

The obtained angular distributions, normalized tentatively to a distribution with mean energy $E_0 \simeq 0.25$ keV, were approximated by means of the formula

$$y(\vartheta) = c(1 + \omega_1 \cos\vartheta),$$

since in our case the higher-order terms in $\cos\vartheta$ in the expansion (1) could be neglected. The calculated values of ω_1 for 11 neutron energies are shown in Fig. 1. The errors indicated are statistical. The curves were calculated with the aid of formula (4) at fixed $a = 1.9 \times 10^{-3}$ and at the indicated values of α_n.

Further reduction of the results consisted of representing ω_1 in the form

$$\omega_1 = a(E - E_0) + b(E^{1/2} - E_0^{1/2}) \qquad (4)$$

and determining the coefficients a and b. Calculations by the least-squares method (which was used also in the determination of ω_1) yielded $a = (1.91 \pm 0.42) \times 10^{-3}$ and $b = (-0.07 \pm 1.96) \times 10^{-3}$, from which we obtained for α_n from (3):

$\alpha_n = (0.3 \pm 9.2) \times 10^{-42}$ cm^3.

A more accurate estimate of the polarizability is obtained by simultaneous reduction of our data and those of Langsdorf et al. (published in [8]) on scattering by lead in the 50 - 160 keV interval. Such a reduction yields a = (1.92 ± 0.20) x 10^{-3} and b = (-0.15 ± 1.16) x 10^{-3}, whence $\alpha_n = (0.7 \pm 5.4) \times 10^{-42}$ cm^3 (see Fig. 2).

We can thus state that, with a probability ~68%, the values of α_n lie in the range

$$-4.7 \times 10^{-42} \text{ cm}^3 < \alpha_n < 6.1 \times 10^{-42} \text{ cm}^3$$

and are of the same order of magnitude as the theoretically expected value (1 - 2) x 10^{-42} cm^3 (literature references are given in the preprint of [6]).

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