If the transitions with $\Delta I = 7/2$ are small (this assumption is quite reasonable), then (3) makes it possible to estimate the pion scattering lengths. The values obtained in this manner are shown in the figure. The right side of (3) is determined mainly by the deviations from the linear form (1) in the decays $K \to \pi^0\pi^0\pi^+$ and $K_{20} \to \pi^+\pi^-\pi^0$, so that we can expect beforehand the lengths determined from (3) and from the pion spectra [7] to lie more or less in the same region. It is seen from the figure that a considerable overlap of the regions does indeed take place. This confirms the consistency of the different experimental data, and consequently also of the obtained possible values of the pion scattering lengths.

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ELECTRIC FORM FACTOR OF THE PROTON AT SMALL MOMENTUM TRANSFERS

B. A. Arbuzov

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Experimental data on the behavior of the proton form factor at small momentum transfers are quite inaccurate [1]. For the electric form factor of the proton $G(q^2)$, the errors in the measurment of the function

$$\phi(q^2) = \frac{1 - G(q^2)}{q^2}; \tag{1}$$

are comparable with the values of the function itself at values $q^2 < 1\ F^{-2}$ ($F = 10^{-13}$ cm), and there are no data below $q^2 = 0.2\ F^{-2}$. It is customarily assumed that in the region of small transfers the form factor is described, with a high degree of accuracy, by the relation $\phi(q^2) = 1/6\ r_0^2$, where $r_0 = 0.8$ F is the mean-square radius of the proton, obtained by extrapolation from the region $q^2 > 1\ F^{-2}$. However, the experimental data leave room for various hypotheses concerning the variation of the behavior of the form factor at small values of q^2. By way of an example, we indicate the hypothetical proton "halo" [2], which was introduced to explain the discrepancies between theory and experiment in the Lamb shift [3] and in spectra of heavy muonic atoms [2].

We have shown in [4] that the same discrepancies can be explained by assuming a small nonlinearity of the equations of electrodynamics. In the case of interest to us, when only the electric field E is significant, this assumption reduces to the following change of the field Lagrangian

$$L = \frac{E^2}{8\pi} + \frac{E^4}{8\pi\, E_0^2} \quad . \tag{2}$$

where $E_0 = e/\ell_0{}^2$, e is the electron charge, and ℓ_0 is the characteristic length, on which experiment imposes the limitation $\ell_0 \lesssim 0.1$ F [5]. The nonlinearity leads to a change of the electron-proton interaction energy, which equals at large distances $r >> r_0$ [4]

$$V(r) = -\frac{e^2}{r}\left(1 - \frac{\ell_0^2}{r^2} + 0\left(\frac{\ell_0^4}{r^4}\right)\right), \tag{3}$$

where a factor of the order of unity has been left out in fron of the term $\ell_0{}^2/r^2$ (this is tantamount to an insignificant redefinition of ℓ_0). The additional term in (3) leads to a shift of the atomic levels, and the length required to explain the discrepancies between theory and experiment in the Lamb shift (the difference amounts to $\Delta\nu = 2.5 \times 10^5\ \text{sec}^{-1}$) is $\ell_0 = 0.12$ F.

We show in this paper that the change of the interaction energy (3) can be detected by measuring the electric form factor of the proton at small momentum transfers. Indeed, if our assumptions are valid, then one measures in the electron-proton scattering experiments not the true charge distribution $\rho(r)$, but the effective distribution $\rho'(r)$, which is defined in terms of the interaction energy as follows:

$$\rho'(r) = -\frac{1}{4\pi e^2}\,\Delta V(r) = \rho(r) - \frac{1}{4\pi e^2}\,\Delta(\delta V), \tag{4}$$

where Δ is the Laplace operator, and according to (3) we have as $r \to \infty$

$$\delta V \to \frac{e^2 \ell_0^2}{r^3} \quad . \tag{5}$$

Calculating the Fourier transform of the distribution $\rho'(r)$, we obtain for $\phi(q^2)$ at small values of q^2 ($q^2 << r_0^{-2}$) the following expression

$$\phi(q^2) = \frac{R^2}{6} - \frac{\ell_0^2}{2}\, ln(q^2 r_0^2)\ ; \tag{6}$$

where R is a constant determined by both the first and second terms in (4), and depends on the form of the true density $\rho(r)$, while the term containing the logarithm is the result of the asymptotic behavior of (5), and the coefficient preceding it does not depend on the form of $\rho(r)$. Since $\ell_0{}^2 << r^2$, the second term in (6) is large only when q^2 and R are very small, and can be set approximately equal to r_0. A sufficiently accurate measurement of the proton form factor at small momentum transfers will make it possible to verify formula (6), meaning also the linearity of the electrodynamic equations. By way of illustration we indicate that according to (6), when q^2 changes from 0.5 to 10^{-3} F^{-2} the function $\phi(q^2)$ changes from 0.12 to 0.16 F^2, i.e., by 30%.

We note that the logarithmic terms of the form factor appear in the nonlinear theory only for charged particles. There should be no such terms for the neutron, in accord with experiment, since measurements of the mean-square radius of the neutron at high energies and in the scattering of slow neutrons by electrons which do not contradict each other [6].

In conclusion, we emphasize once more the importance of measuring the proton form factor at low transfers; such measurements can be made with strong-current electron accelerators with energies 10 = 100 MeV.

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CONCERNING THE ORIGIN OF SUPERHEAVY ELEMENTS

E. E. Berlovich and Yu. N. Novikov
A. F. Ioffe Physico-technical Institute, USSR Academy of Sciences

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Recently, P. Fowler's group (private communication) observed in the cosmic ray spectrum nuclei with charge $Z \approx 108 \pm 2$. According to the notions prevailing to date [1, 2], such heavy elements cannot result from the r-process occurring in supernova flares. The reason is that the r process is terminated as a result of the neutron-induced nuclear fission, which occurs, according to the latest estimates of F. Hoyle and W. Fowler [3], at mass numbers $A \approx 270 - 275$ ($Z \approx 93$). These estimates were made with allowance for the influence of the symmetry term $[(N - Z)/A]^2$ in the surface energy of the nuclear drop on the fissility, but without allowance for shell corrections [4,5] in the mass formula; these corrections become particularly large in the region of magic nucleon numbers, and alter appreciably both the height and the width of the barrier [6].

Inasmuch as the termination of the r-process occurs, according to the estimates of [3], when the number of neutrons is close to the magnic $N = 184$, allowance for the shell corrections in the calculation of the course of the r-process becomes essential.

The path of the r-process can be calculated by assuming statistical equilibrium in the ($n\gamma$) and (γn) reactions; this leads to the condition [1]

$$B_n(Z, N) = T_9 / 5{,}04\,(34{,}07 - \log n_n + 1{,}5 \log T_9), \qquad (1)$$

under which the capture of neutrons by the nucleus (Z, N) stops. In formula (1).