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ON POLARIZABILITY OF THE NEUTRON AND ITS MEAN SQUARE RADIUS

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From ref.[1] follows the most exact for the present value for the mean square radius of charge distribution in the neutron, i.e.,

$$<r_E^2> = 6\left(\frac{\partial G_E}{\partial q^2}\right)_{q^2=0} = 3\,\frac{\hbar^2}{Me^2}\,a_{ne}, \tag{1}$$

where $(\partial G_E/\partial q^2)_{q^2=0}$ is the slope of the neutron form factor at zero square of the transferred momentum, and a_{ne} is the amplitude of neutron-electron interaction. In ref.[1] the value of $a_{ne} = (-1.378 \pm 0.018)\ 10^{-3}$ fm corresponding to $\left(\frac{\partial G_E}{\partial q^2}\right)_{q^2=0} = -0.0199 \pm 0.0003$ fm^2 was obtained from the comparison of experimental data on coherent scattering amplitudes b_{coh} of neutrons on Bismuth and Lead measured using the neutron gravity reffractometer with those on scattering cross sections of neutrons on the nuclei of the same elements at an energy of 1.26 and 5.19 eV. This value of $\left(\frac{\partial G_E}{\partial q^2}\right)_{q^2=0}$ is usually used for the analysis of experimental data on scattering of high energy electrons by deuterons (see, for example, ref.[2]).

The purpose of the present paper is to draw attention to the necessity of taking into account the effect of the electrical polarizability of the neutron on the value of a_{ne} during the analysis of experimental data obtained in ref.[1]. As it will be shown below this effect causes a considerable increase of the error in determining the a_{ne} value.

Let us use the formalism conventionally used for the problems of scattering of a particle on a sum of short-range and long-range potentials (see, for example, ref.[3]). The neutron scattering amplitude f_t may be expressed through the phases of nuclear δ_ℓ, neutron-electron η_ℓ and polarization ξ_ℓ scattering. At low energies, when only the s-scattering is important, one has

$$f_t = \frac{1}{2ik}(S_0 - 1)\exp[2i(\eta_0 + \xi_0)] + \frac{1}{k}\sum_\ell (2\ell+1)\sin(\eta_\ell + \xi_\ell)\exp[i(\eta_\ell + \xi_\ell)]P_\ell(\cos\theta), \tag{2}$$

where

$$S_0 = \left(1 - i\sum \frac{\Gamma_n}{\Delta E + i\Gamma/2}\right)\exp(2i\delta_0).$$

Within the Born approximation and in the absence of resonances (their effect on the cross sections of Bismuth and Lead at energies 1.26 and 5.19 eV is weak and accounted for in ref./1/) we have:

$$\mathrm{Re} f_t(0) = \frac{1}{k}\sin\delta_0\cos[\delta_0+2(\eta_0+\xi_0)] + z a_{ne} + a = b_{coh} \qquad (3)$$

$$\mathrm{Im} f_t(0) = \frac{1}{k}\sin\delta_0\sin[\delta_0+2(\eta_0+\xi_0)] = \frac{k\sigma_s}{4\pi}, \qquad (4)$$

where

$$a = \frac{M\alpha}{2R}\left(\frac{ze}{\hbar}\right)^2 qR\left(\frac{\sin qR}{(qR)^2} + \frac{\cos qR}{qR} + \mathrm{si}\, qR\right)$$

is the polarization scattering amplitude/4/, α is the coefficient of electrical polarizability of the neutron, $q = \frac{2}{\lambda}\sin\theta/2$

$$\eta_0 = \frac{a_{ne}k}{2}\int_0^\pi f\left(\frac{\sin\theta}{\lambda}\right)\sin\theta\, d\theta \qquad \xi_0 = \frac{M\alpha}{R}\left(\frac{ze}{\hbar}\right)^2 k\left(1-\frac{\pi}{3}kR\right)$$

$f\left(\frac{\sin\theta}{\lambda}\right)$ is the atomic form-factor.

The relationships (3) and (4) contain the unknown values of δ_0, a_{ne}, and α. They can be found by substituting into (3) and (4) of experimental values from ref./1/ (at two values of σ_s). The results are listed in table 1. It shows that the data from ref./1/ allows one to find a_{ne}, but with a large error.

Table 1

Bismuth

a_{ne}	$(-1.5\pm0.7)\times10^{-3}$ fm	$(-1.4\pm0.8)\times10^{-3}$ fm
α	$(12\pm12)\times10^{-3}$ fm^3	$(6\pm6)\times10^{-3}$ fm^3

The authors of ref./5/ obtained a value of $a_{ne} = (-1.33\pm0.03)\times10^{-3}$ fm (with the account for the Schwinger scattering)*. One may try to find α using this value of a_{ne} in the analysis of data from ref. /1/. It appears to be the complex value, which might indicate to some contradiction between the data on b_{coh} and σ_s (ref./1/) and those on a_{ne} (ref./5/).

* The results of other works on a_{ne} contain even larger errors, and some of them should be corrected for the effect of the polarizability of the neutron.

The minimum real value of $\alpha \simeq 9\cdot10^{-4}$ fm^3 corresponds to the value of $a_{ne} \simeq -1.37\cdot10^{-3}$ fm. The value of α increases with increasing $|a_{ne}|$. Table 2 gives the results of data procession (ref./1/) under assumption that a_{ne} is determined by the Foldy interaction (ref./6/) giving

$$a_{ne} = \mu_n \frac{e^2}{2Mc^2} = -1.468\times10^{-3}\ \mathrm{fm}.$$

Table 2

$a_{ne} = -1.468\times10^{-3}$ fm

	Bismuth		Lead	
	1.26 eV	5.19 eV	1.26 eV	5.19 eV
α	$(12\pm2)\times10^{-3}$ fm^3	$(9\pm2)\times10^{-3}$ fm^3	$(12\pm2)\times10^{-3}$ fm^3	$(13\pm2)\times1+$ fm^3

$\bar{\alpha} = (11\pm1)\times10^{-3}$ fm^3

Let us note in conclusion that the above information about α is not in contradiction with the value of $\alpha = (9\pm5)\times10^{-3}$ fm^3 obtained in ref./7/ in the analysis of slow neutron scattering on ^{186}W.

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Александров Ю.А. E3-82-12

О поляризуемости нейтрона и его среднеквадратичном радиусе

Обращается внимание на то, что при получении величины наклона электрического формфактора нейтрона из данных по рассеянию медленных нейтронов на атомах свинца и висмута необходимо учитывать влияние поляризуемости нейтрона.

Работа выполнена в Лаборатории нейтронной физики ОИЯИ.

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Alexandrov Yu.A. E3-82-12

On Polarizability of the Neutron and Its Mean Square Radius

Attention is paid to the fact that it is necessary to take into account the neutron polarizability effect when obtaining the values for the slope of the neutron electric form factor from the data on slow neutron scattering on Lead and Bismuth atoms.

The investigation has been performed at the Laboratory of Neutron Physics, JINR.

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