On the influence of charge nuclear form-factors on the neutron scattering

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Abstract

It is shown that it is necessary to take into consideration the influence of charge nuclear form-factors obtaining electric neutron polarizability from data ten MeV neutron scattering by heavy nuclei.

Neutron amplitude of neutron-atom scattering can be written [1] as

$$b(E,\varphi) = b_{nuc}(E,\varphi) + b_{ne}Z\,[f(E,\varphi) - h\,(E,\varphi)] + b_{pol} \quad (1)$$

where b_{nuc} is nuclear scattering amplitude, b_{ne} is neutron-electron scattering amplitude, f is atomic form-factor, h is charge nuclear form-factor, b_{pol} is amplitude by the neutron electric polarizability.

At low neutron energies h=1, $b_{ne}Zh$ does not depend from energy and this term can be included to b_{nuc}. However at neutron energy of the order of ten MeV and higher, h<1 and changes with energy. The purpose of this work is to show that this proposition is true for the lead for example.

If nuclear charge density $\rho(r) = \rho_0$ at $r \leq R$, where R is the nuclear radius and $\rho(r) = 0$ at r>R, then h(q) can be writing as [2,3]:

$$h(q) = \frac{3(\sin qR - qR\cos qR)}{(qR)^3} \quad (2)$$

where $q = 2k\sin\varphi/2$, $k=2\pi/\lambda$, λ is neutron wave length.

If $\rho(r) = \rho_0(-r/d)^2$, where $d^2 = -2/3 <r^2>$, and mean square charge radius $<r^2> =$

$$= 4\pi \int_0^\infty \rho(r) r^4\, dr, \text{ then}$$

$$h_g(q) = \exp(-q^2d^2/4) \quad (3)$$

(see[2,3])

For heavy nuclei $<r^2>^{1/2} = 1.2A^{1/3}$ is a good assumption and the results of calculation h and h_g (according (2) and (3)) for neutron scattering of 14 MeV neutrons are in Table 1.

Table 1

φ	1°	4°	10°	20°	30°
h	0.998	0.979	0.875°	0.569°	0.234°
h_g	0.998	0.973	0.842°	0.506°	0.202°

In Table 2 one can see the results for the 14 keV neutron scattering

Table 2

φ	1°	10°	20°	30°
h	0.9999	0.9999	0.9995°	0.9989°

From Tables it is conclude that charge nuclear form-factors change with angle at 14 Mev and does not change at 14 keV.

It is interesting to compare the angular dependence of Zb_{ne} h value and b_{pol} one. The expression b_{pol} can be written (see e.g. [4]) as:

$$b_{pol} = \frac{\alpha_n m}{R}\left(\frac{Ze}{\hbar}\right)^2 qR\left[\frac{\sin qR}{(qR)^2} + \cos qR + si(qR)\right] \quad (5)$$

where

$$si\,(qr) = Si(qr) - \pi/2 = -\int_{qR}^{\infty} \frac{\sin x}{x} dx \quad (6)$$

The value of (6) one can find in tables [5] , and the value of $\frac{\alpha_n m}{R}\left(\frac{Ze}{\hbar}\right)^2 = 38.8 \times 10^{-16}$ cm at $\alpha_n = 1.2 \times 10^{-42}$ cm^3.

The results of calculations for Pb ($b_{nuc} = -0.94 \times 10^{-12}$cm) one can find in Table 3

Table 3

φ	0^o	4^o	10^o	20^o
$\lvert b_{ne}Zh \rvert$, cm	1.31×10^{-14}	1.28×10^{-14}	1.15×10^{-14}	0.75×10^{-14}
$\lvert b_{pol} \rvert$, cm	7.76×10^{-15}	5.25×10^{-15}	2.35×10^{-15}	0.093×10^{-15}
$b_{ne}Zh/b_{nuc}$	0.014	0.014	0.012	0.008
$b_{ne}Zh/b_{pol}$	1.70	2.45	4.85	81.0

From Table it follows that at angles from 0^o to 20^o the relation $b_{ne}Zh$ / b_{nuc} changes from 0.014 to 0.008 but the contribution of $b_{ne}Zh$ exceeds b_{pol} from 1.7 up to 81 times. The difference $\Delta b_{nuc} = Zb_{ne}[h(0^o)-h(20^o)] = 0.56 \times 10^{-14}$cm, but $\Delta b_{pol} = b_{pol}(0^o)- b_{pol}(20^o) = 0.77 \times 10^{-14}$cm and Δb_{pol} is comparable with Δb_{nuc}.

Thus, as the calculations show, it is necessary to take into consideration the influence of charge nuclear form-factors obtaining the electric neutron polarizability from neutron scattering experiments in ten MeV region energy on heavy nuclei. Possibly the data of Obninsk group will change after this procedure. They obtained [6] too big value of $\alpha_n \approx 10^{-40}$cm^3.

References

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