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ON POSSIBLE DIFFRACTION EFFECTS IN THE n, e-SCATTERING EXPERIMENT

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1. Soon after the appearance of a classical work of E.Fermi and L.Marshall [1] reporting one of the first attempts to discover *n,e*-scattering, A.I.Akhieser and I.J.Pomeranchuk announced in a brief paper [2] that a small forward-backward asymmetry of neutron scattering [1] could be caused by the interference of neutron waves scattered on neighboring atoms. Basing on the only fact that two non-interacting atoms cannot be closer than 2R to each other (R is the atom's radius) the authors of [2] have shown that a diffraction pattern must be observed. This effect arises due to addition of a "diffraction" term to the differential nuclear scattering cross section a^2 and the *n,e*-contribution with the scattering length a_{ne}, charge number *Z* and the electron form factor $f(\vartheta)$:

$$\sigma_s(\vartheta) = a^2 + 2aa_{ne}Zf(\vartheta) + a^2 \cdot 4\pi(2R)^3 ng(\vartheta), \tag{1}$$

where $g(\vartheta)$ is the function of the scattering angle:

$$g(\vartheta) = \frac{\cos\eta}{\eta^2} - \frac{\sin\eta}{\eta^3}, \qquad \eta = \frac{8\pi}{\lambda} R \sin\frac{\vartheta}{2}, \tag{2}$$

n is the density of atoms and λ is the neutron wavelength.

Taking $\delta = \sigma(\vartheta_1)/\sigma(\vartheta_2) - 1$, where $\vartheta_1 < 90^0$, $\vartheta_2 > 90^0$, as an asymmetry measure we have (if the two last terms in (1) are much less than a^2)

$$\delta = 2(a_{ne}/a)Z\Delta f + 4\pi(2R)^3 n\Delta g, \tag{3}$$

where $\Delta f = f(\vartheta_1) - f(\vartheta_2)$, $\Delta g = g(\vartheta_1) - g(\vartheta_2)$. Thus, in order to observe the diffraction effect it is necessary to have the experimental δ values obtained at different gas pressures P. The data on δ will be a linear function of P (because $n \sim P$).

2. Such data from the well-known work [3] are presented for two gases in Fig.1. It seems quite obvious that the sloping straight lines 2 describe the experimental points better than the horizontal lines 1. Therefore, using the approximations

$$10^5 \cdot \delta = -(290 \pm 15) - (34 \pm 20)P \qquad \text{for Kr}, \tag{4}$$

$$10^5 \cdot \delta = -(483 \pm 16) - (27 \pm 14)P \qquad \text{for Xe}, \tag{5}$$

it is more correct to take the first terms of (4) and (5) (corresponding to the lines 3) for the *n,e*-effect and the second terms for the diffraction effect. This results in the following change of a_{ne} values

$a_{ne} = -(1.23 \pm 0.10) \cdot 10^{-3}$ fm instead of $-(1.37 \pm 0.05) \cdot 10^{-3}$ fm for Kr,

$a_{ne} = -(1.25 \pm 0.05) \cdot 10^{-3}$ fm instead of $-(1.32 \pm 0.03) \cdot 10^{-3}$ fm for Xe

as well as in a possible discovery of neutron diffraction in two single-atom gases with the probability ~91% for Kr and ~95% for Xe.

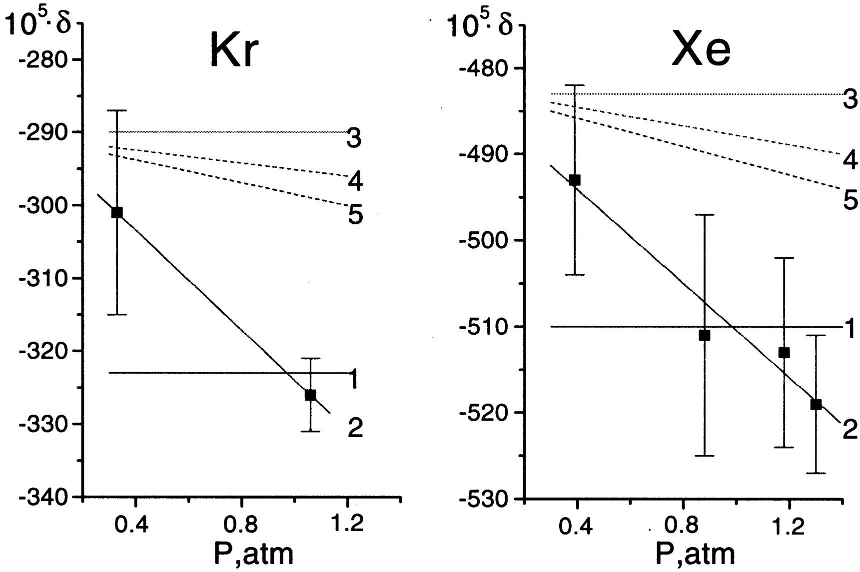

Fig.1. The scattering asymmetry from the experiment of [3] at different pressures of gases. Lines: 1 – average values accepted by the authors of [3]; 2 – functions of P which should be accepted; 3 – effects of the *n,e*-scattering; 4 – summary effects of the *n,e*-scattering and the diffraction after [2] at kT=0.028 eV; 5 – the same at kT=0.020 eV.

3. Regarding the prediction in [2], it is necessary to calculate the average value of the second term in (3) using a Maxwell energy distribution of neutrons with the thermal energy kT. The results of the integration are pictured in Fig.1 by dashed lines. These results are determined by the chosen kT value and do not virtually depend on the atomic radius R in the interval 1 – 2 Å due to

peculiarities of the oscillating function of the neutron energy (2). The lines 4 correspond to kT=0.028 eV, the lines 5 – to kT=0.020 eV.

4. It is quite strange that the authors of [3] left without comment the visible influence of P on δ in Fig.1. It is especially strange because they have mentioned the use of different gas pressures: "These measurements were made in order to test for the possible presence of diffraction effects associated with a tendency of gas at moderate pressure to exhibit structure effects similar to those found in liquids".

If diffraction on a single-atom gas occurs or not - the answer can be only obtained from special experiments with monoenergetic neutrons (or even better, with the time-of-flight method) at higher gas pressures.

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References

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Мицына Л. В. и др. E3-2002-40

О возможных дифракционных эффектах в эксперименте по n, e-рассеянию

На основе ранних предсказаний Ахиезера и Померанчука о существовании нейтронной дифракции на одноатомных газах проанализированы известные результаты работы Крона и Ринга. Обнаружен определенный добавочный к n, e-рассеянию эффект $(34 \pm 20) \cdot 10^{-5}$ для криптона и $(27 \pm 14) \cdot 10^{-5}$ для ксенона.

Работа выполнена в Лаборатории нейтронной физики им. И. М. Франка ОИЯИ.

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Mitsyna L. V. et al. E3-2002-40

On Possible Diffraction Effects in the n, e-Scattering Experiment

An analysis of known results of Krohn and Ringo was carried out under the influence of the prediction of Akhieser and Pomeranchuk concerning neutron diffraction in a single-atom gas made long ago. In addition to n, e-scattering a certain effect of $(34 \pm 20) \cdot 10^{-5}$ for krypton and $(27 \pm 14) \cdot 10^{-5}$ for xenon was observed.

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

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