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EXPERIMENTAL INSTALLATIONS FOR INVESTIGATION OF SCATTERING NEUTRON ANGLE DISTRIBUTION

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The two experimental installations for measurements of the angular distribution of the quasi-monochromatic neutron beams IASD-1 and IASD-2 (Installation for Angle Scattering Distribution) scattered by investigated samples are described here. A vacuum cylinder chamber in the middle of which an electromechanical knot is placed for automatic transposition of scattering samples is the basis of both installations. The neutron beam is transported to the sample and is taken from through the tubes closed by thin aluminum diaphragms. Both installations have the identical electronic measurement circuits. Special program ZERKIN-3 is used for management of measurement process. The measurements of the angular distributions are relative. As the standard, ^{208}Pb sample is used. Background spectrums are measured when the beam is screened with polyethylene sample. The IASD-1 installation allows conducting the measurements under any angle in the range 30 - 150°. Registration of the scattered neutrons takes place simultaneously with four detector assemblies. One assembly consists of seven helium counters CHM-17 with the one pre-amplifier and individual radiation shielding. The IASD-2 installation is intended for measurements under the fixed angles of 15, 30, 55, 90, 125, 150 and 165°. For neutron registration LND-2527 and LND-281 counters are used, which are placed in common radiation shielding filled with boron carbide. The above mentioned detector assemblies with CHM-17 can be also used.

1. Introduction

The set of filter components (including separated isotope materials) that is presented in the Institute for Nuclear Research (INR) of NASU, enables to get the quasi-monochromatic neutron beams in the range of energies from thermal to several hundred keV. The number of filters provides high enough intensity of neutron flux at the output, what is sufficient for measurements of differential neutron scattering cross sections with high accuracy. These differential cross sections can give the valuable information about the interaction of neutrons with nuclei. The gained experience of the precise measurements of total neutron cross sections in combination with cross sections of scattering may give the possibility to receive the cross sections of neutron absorption in nuclei. It follows to say, that in the indicated range of energies for today there is a lack of experimental data.

The first measurements of differential neutron scattering cross sections with filtered beam were done at the beginning of the eightieth in the last century at the WWR-M reactor under the direction of Prof. Vertebnyi. The research group conducted measurements of differential cross sections on the filtered neutron beam with average energy 144 keV for natural lead, ^{238}U and ^{232}Th [1]. As the neutron detector it was used the proton recoil counter CHM-38.

In these measurements the noticeable contributions to neutron scattering were observed from neutrons with orbitals l = 1 and 2, that specifies an anisotropic angular distribution of the scattered neutrons at this energy.

With the purpose of continuation of such investigations in INR in Neutron Physics Department there were developed and constructed the two spectrometry installations IASD-1 and IASD-2 for measurements of quasi-monochromatic neutrons scattered by investigated samples under the number of angles simultaneously.

2. General features for both installations

The main components of each installation are: 1) vacuum cell for neutron beam conducting and location of investigated samples; 2) neutron detector and registration system; 3) system of radiation shielding.

Installations for measurements of differential cross sections were set on the horizontal channel GEK-8 of WWR-M reactor. Forming of quasi-monochromatic beams of neutrons takes place in three disks of shutter and outside collimator (Fig. 1).

Radiation shielding of experimental equipment on GEK-8 consists of two compartments. The first compartment is intended for outside collimator and device for transposition of standards during measurements of total neutron cross sections, the second – for neutron detectors for measurements of total neutron cross sections and installations for angular measurements of the scattered neutrons. The scheme of experimental equipment at the channel is presented on (Fig. 2).

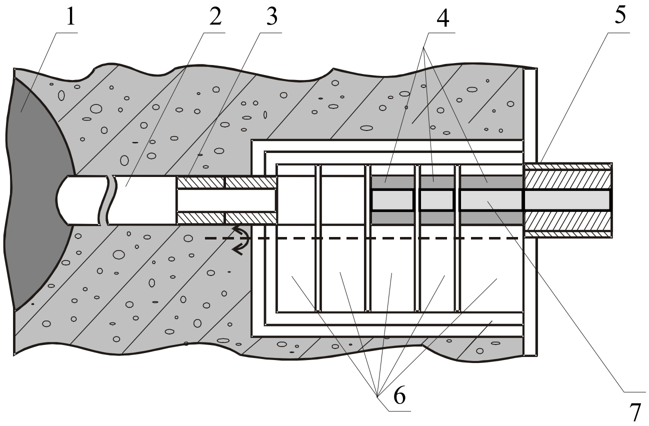

Fig. 1. Construction of neutron filtered beam to receive quasi-mono-chromatic neutron flux. *1* – Beryllium reflector; *2* – horizontal channel tube; *3* – preliminary collimator; *4* – filter-collimator assembles; *5* – outside collimator; *6* – shutter disks; *7* – filter assembles.

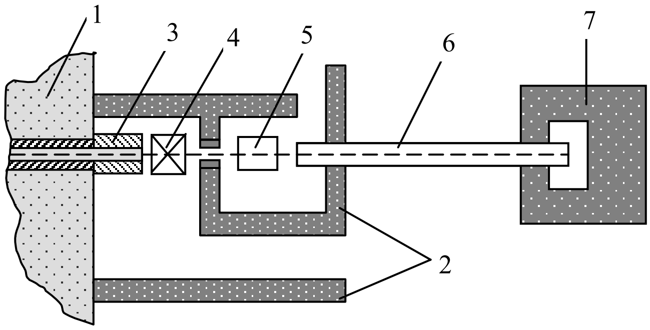

Fig. 2. Scheme of scattering measurements. *1* – reactor biological shielding; *2* – radiation shielding of installation; *3* – outside collimator; *4* – device for sample moving; *5* – installation for angular measurements; *6* – tube for beam conducting to catcher; *7* – beam catcher.

The vacuum chambers of installations at measurements are placed on the special supports, that allow to adjust them on a beam.

The neutron beam is conducted to the chamber and is taken from it through the vacuum segments of neutron tubes, the butt-ends of which are closed by thin aluminum diaphragms. Inside the chambers the electromechanical devices are located for placing of experimental samples and their automatic transposition.

The system of neutron detectors so far consists of 4 detectors and measurements can be conducted on 4 samples in series: two experimental samples, standard (^{208}Pb) and holder of standard. It is due to the peculiar properties of registration and accumulation program for experimental spectrums. In the stage of completion there is a new system of registration and storage of spectrums and its software that will give possibility to use 8 detectors simultaneously.

It is worth to notice that during conducting of measurements on powder-like samples in one of holders it is necessary to put the equivalent of container for powder. In this case a standard is also placed in a similar container, to take into account the part of neutrons scattered in container. All containers preliminary have to be adjusted on the neutron beam for an account at treatment of experimental spectrums for possible non-identity of containers.

At measurements, the detectors are placed in horizontal half-plane round a chamber. Signals from every detector on-line are passed to the measuring and storage center, where the necessary electronic equipment is concentrated for registration and accumulation of experimental spectrums. The control systems and electronic measuring devices of both installations are identical (Fig. 3).

In the electronic measuring section the special block of detector numbering (DN) enters except for traditional electronic blocks (preamplifier, main amplifier and digital converter). Signals from every detector at first enter this block, where the number of detector is appropriated to them, and already then it goes to digital converter. The management of this system during measurements is executed by the special program ZERKIN-3.

Radiation shielding of separate detectors and of all installation constitute the system of radiation shielding. Radiation shielding for each of installations is done individually.

The background measurements at research of differential cross sections are conducted at shut-down of neutron beam by the polyethylene sample (PS) with proper thickness (depending on energy of quasi-monochromatic neutrons) or by a screen from material, that has rather strong resonance at this filter energy. The shutting of beam is carried out by the device for transposition of samples during the measurements of the total cross sections (4) (see Fig. 2.)

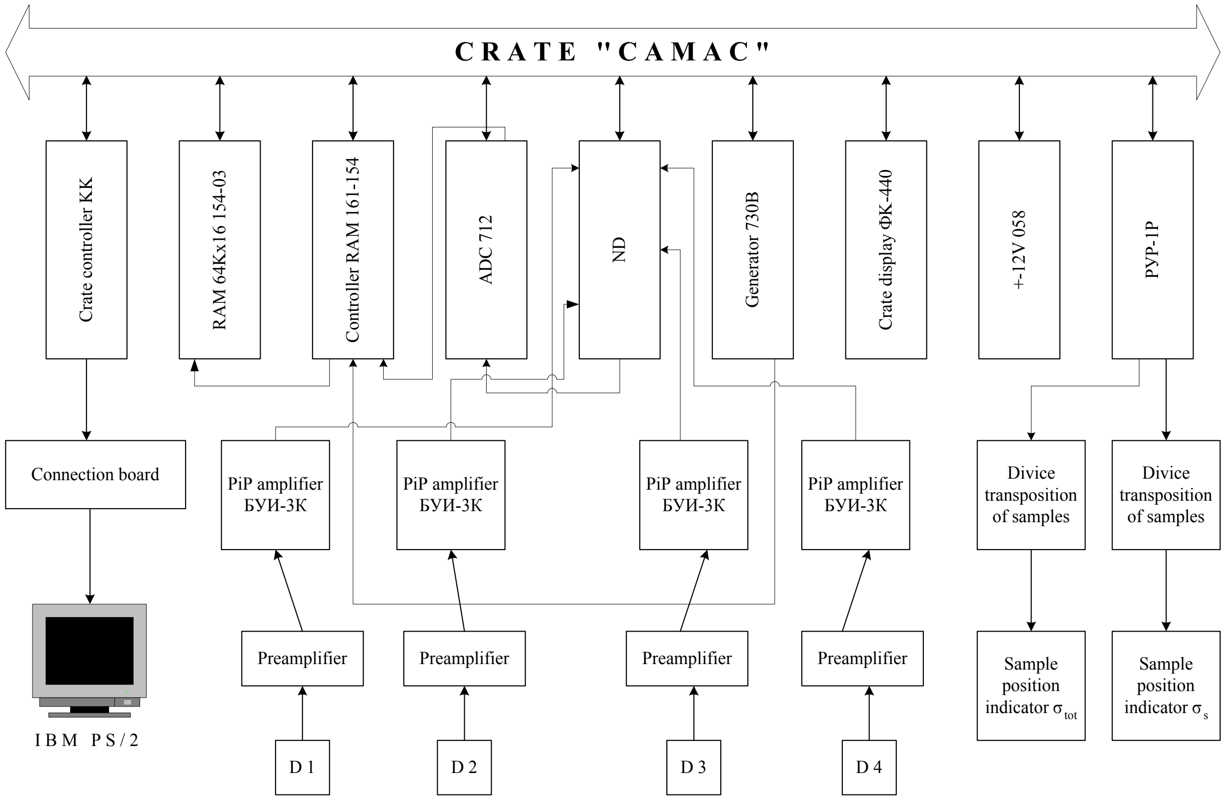

Fig. 3. Flow block of spectrometry section in installation for differential cross section measurements.

The typical sequence of measurements in one cycle is the following: sample № 1, sample № 1 + PE, ^{208}Pb, ^{208}Pb + PE, sample № 2, sample № 2 + PE, sample holder alone and sample holder + PE. Time of irradiation of every sample on the beam is 60 sec, the time of samples transposition is 5-7 sec; the amount of cycles in one display is 25 - 30. Thus, when the measurements are conducting for 4 angles, we receive 32 spectrums.

3. Spectrometry installation IASD-1

The vacuum chamber of the IASD-1 installation is an aluminum cylinder with 130 mm height and 214 mm diameter; its butt-ends are closed by flanges. One of them is the foundation for an electromechanical device for investigated samples; the second has the special configuration that provides the identical thickness of aluminum on the way of scattered neutrons from the sample to detector; it is due to the thin-walled semi-cylinder lug on the flange, the center of which coincides with the center of sample-scatterer, that is on the beam. Neutron guides have 74 mm internal diameter and 850 mm length. The butt-ends of these guides are closed by aluminum diaphragms with 1mm thickness. The axis of chamber occupies the horizontal position relative to the beam. The scheme of chamber with the electromechanical device and the position of neutron detectors is presented on Fig. 4.

The device for stationing of samples, as it can be seen from Fig. 4, has the shape of five-ray star. At the ends of rays (65 mm distance from the center) on thin spokes the holders for samples are set. The holder is ring-shaped with 30.4 mm diameter, 6 mm width and 0.1 mm thickness. For prevention of sample fall-out the holders have the 0.5mm welt and from other side a sample is fixed in a holder with a spring clamp. The centers of samples inserted at holders are at the75 mm distance from the rays of five-ray star, to prevent the influence of installation structure components on the experimental results.

Every sample at their transposition occupies the fixed position on the axis of chamber. The special reducing gear of "maltese cross" type is used for the transmission of engine axis rotation to the rotation of five-ray star with samples and that provides the fixing of samples position on the neutron beam.

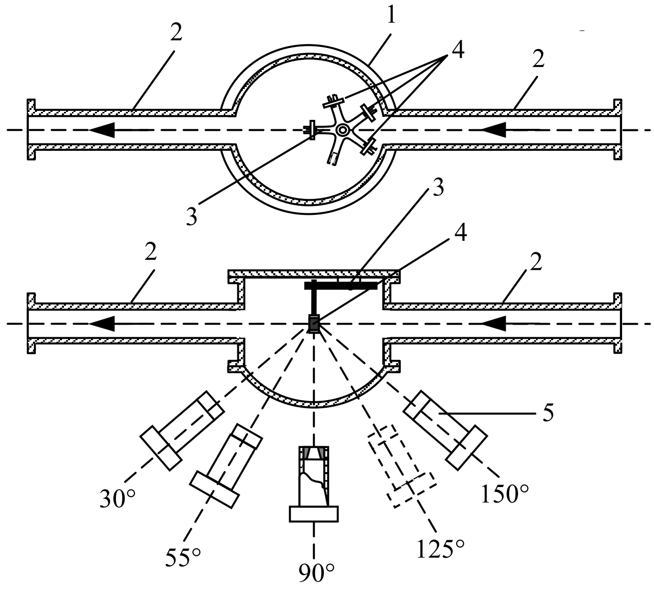

Fig. 4. Installation IASD-1: vacuum chamber scheme. *1* – chamber; *2* – neutron guide; *3* –sample changing gear; *4* – scatterer; *5* – neutron detector with preamplifier.

At right angle to the surfaces of flange in a horizontal plane there is set the metallic slab for neutron detectors placing. Detectors can be set under any angle in relation to the axis of neutron beam, as each of them is the separate construction. A mobile platform is also foreseen with set on it of one detector; it is possible to remove this platform on the slab at any angle within the limits of 30 - 150°. Direction of axis over which a platform is rotated coincides with the center of sample that is at the beam. Due to this, it is possible to conduct the measurements under necessary angles with the same detector. It enables to check up the isotropic dispersion of scattering neutrons on the certain sample.

For registration of the scattered neutrons, five specially designed detectors were used. Every detector is the assembly of seven helium counters CNM-17 (18 mm diameter, 220 mm length, 7 at pressure), which works with one preamplifier. For every assembly of the counters the units were picked up with the identical gas amplification, so that no expansion of helium peak took place in spectrums. These assemblies have the individual radiation shielding as the cylinder thin-walled container (100 mm external diameter, 300 mm length) filled with the boron carbide. Internal diameter in a container for detector assembly was 65mm. Detector assemblies were placed on the slab so that the axis of the assembly was in a horizontal plane on one line with the center of the sample on the neutron beam.

The measurements of the angular distributions at the IASD-installation were executed under the angles 30, 55 (60), 90, 125 (120) and 150° at quasi-monochromatic neutron energies 2, 59 and 133 keV. The part of measurements was done under the angles 60 and 120°.

4. Spectrometry installation IASD-2

The IASD-1 installation served in practice as a test bench for working off the method of angular distribution measurements of the scattering neutrons and development of codes for measurements and treatment of experimental spectrums.

Experience of IASD-1 exploitation showed how it is possible to perfect this system. It was developed and manufactured the IASD-2 installation. At its construction a purpose was in mind to remove as much as possible the experimental sample from construction elements placed in the vacuum chamber and also to provide the possibility of the neutron spectrum measurements additionally under the angles 15 and 165°. The schematic draw of IASD-2 installation is presented in Fig. 5.

IASD-2 was planned for the simultaneous operation with four samples. A few words about the device for holding the samples:

its elements are mounted directly on “maltese cross”;

holders of samples as rings (30.4 mm internal diameter) with cut out 90° sector are fixed on spokes with 2 mm diameter and 80 mm length;

cuts in rings were directed to the side of detector platform, that provides the absence of construction material on the way of neutrons from the sample to detector;

spokes of holders are twisted in guides, that are inserted into the sockets and are fixed there with the special spring clamps;

the assemble ring-spoke-guide, as a single whole, can be easily taken out or inserted into the sockets, that allows quickly replace the samples in holders.

For neutron registration, the detectors on the base of hydrogen counters LND-281 are foreseen and also on the base of helium counters LND-2527. The set of detectors was created on the base of these counters, each of them was the unified construction of a counter and preamplifier. These constructions, as well as preamplifier itself, were developed and manufactured in our laboratory.

Detectors were placed in common shielding (filled with B_4C) which consists of two parts under the fixed angle 15, 30, 55, 90, 125, 150 and 165°. The basic container, 120 mm height, was intended for placing of seven detectors LND-281 and was stationary fastened at the platform. Aluminum tubes with 300 mm length and 38.75 mm internal diameter were set inside this container. Other parts of shielding were made as separate containers (130 × 135 × 120) mm, which during operation with helium counters, were joined to the first part.

Now the IASD-1 installation is demounted from GEK-8 channel and IASD-2 has been installed and methodologically tested.

5. Measurement and handling peculiarities of experimental results

The relative measurements foresee the use of two samples: experimental sample and standard sample. The differential scattering cross section in the laboratory system of co-ordinates (LS) is determined from comparison of detector response on the scattered neutrons for these samples. We have to notice, that standard sample must satisfy the following requirements:

at first, the scattering cross section is dominant above the cross sections of other processes, namely, $\sigma_{tot} \approx \sigma_s$;

secondly, a standard must have the resolved structure of resonances in the energy region of quasi-monochromatic neutrons;

thirdly, the atomic number of standard nucleus must be more than 100.

The last requirement is related to that in this case the scattering angle in LS is practically identical with angle in the center of mass system (CM). Nuclides, which are in the region of two-magic nuclei, answer the mentioned requirements. Just following these considerations, ^{208}Pb was selected as a standard.

It is necessary to mark, that before the measurements with investigated sample begin, the very accurate measurements with the same detector precede using standard sample. It is conditioned with necessity to know the angular distribution of the scattered neutrons on a standard.

The approach to measurements and treatment of their results is as follows: we consider that the investigated sample has the thickness n_x, and standard – n_{pb} atom/cm^2 and the incident beam of quasi-monochromatic neutrons has the average energy E, flux F and effective area S.

We enter such denotations: $\sigma'_{Pb} \equiv \dfrac{d\sigma_{Pb}(\theta)}{d\Omega}$ for standard; $\sigma'_x \equiv \dfrac{d\sigma_x(\theta)}{d\Omega}$ for investigated sample; $d\Omega = \sin\theta\,\Delta\theta\,\Delta f$, where θ is the scattering angle, f – azimuthal angle.

In the case of isotropic neutron scattering on a standard, the differential cross section for ^{208}Pb is determined by relationship: $\sigma'_x = \dfrac{\sigma_{Pb}}{4\pi}$

At the relative measurements, the relation of counting rates for neutrons scattered on the investigated sample and on a standard is measured in experiment.

We write down the counting rates for the sample N_x and standard N_{Pb} as:

$$N_x = F\cdot S\cdot n_x\cdot\sigma'_x\cdot\varepsilon_x\cdot\Delta\Omega_x, \qquad N_{Pb} = F\cdot S\cdot n_{Pb}\cdot\sigma'_{Pb}\cdot\varepsilon_{Pb}\cdot\Delta\Omega_{Pb}, \tag{1}$$

where ε_x and ε_{Pb} - efficiencies of registered neutrons scattered by sample and standard, accordingly.

If these measurements are done in the same geometry and with the same detector, then $\Delta\Omega_x = \Delta\Omega_{Pb}$, and F and S are common. Then the relation of counting rates assumes the following form:

$$\frac{N_x}{N_{Pb}} = \frac{n_x\cdot\sigma'_x\cdot\varepsilon_x}{n_{Pb}\cdot\sigma'_{Pb}\cdot\varepsilon_{Pb}}. \tag{2}$$

If the value σ'_{Pb} is known, then all the values in expression (2), except for σ'_x, are known too or they can be calculated. Just from this relation the differential cross section of neutron scattering can be determined for the investigated sample at the angle θ in LS.

We consider the situation, when the angular distribution of scattering by ^{208}Pb differs from, isotropic, that is conditioned by influence of orbital moments with $l > 0$. We believe that the differential cross section of scattering on ^{208}Pb can be described taking into account the orbital moments with l = 0, 1, 2, 3. Then the differential cross section for ^{208}Pb can be written as follows:

$$\sigma'_{Pb} = \frac{\sigma_{Pb}}{4\pi}(1 + A_1P_1 + A_2P_2 + A_3P_3), \tag{3}$$

where A_1, A_2, A_3, are the values proportional to amplitudes of contributions to neutron scattering with l = 1, 2, 3, and P_1, P_2, P_3 are the Legender polynomials for these orbital moments.

If $A_1 = A_2 = A_3 = 0$, then the angular distribution of the scattered neutrons is isotropic. In this case the differential cross section of the investigated sample can be calculated with formula (2).

We believe that the functions P_1 and P_3 are anti-symmetric in relation to the angle 90°. If $A_1 \neq 0$, and $A_3 \neq 0$, and $A_2 = 0$, then using a formula (3) through the experimental value σ_s for the standard nuclei it is possible to find the semi-sum of their differential cross sections for two symmetric relatively 90° angles θ_1 and θ_2:

$$\frac{1}{2}(\sigma'_{Pb}(\theta_1) + \sigma'_{Pb}(\theta_2)) = \frac{\sigma_s}{4\pi}. \tag{4}$$

When $A_2 \neq 0$ then the relationship (4) will be correct for the angles close to $\theta_1 = 55°$ and $\theta_2 = 125°$.

At the arbitrary values of A_1, A_2, A_3 and angles $\theta_1 = 55°$ and $\theta_2 = 125°$ the sum of effects of dispersion of neutrons on ^{208}Pb, using (1), can be written down, as follows:

$$\frac{N_{Pb}(55^0)}{\varepsilon_{Pb} \cdot \Delta\Omega_{Pb}} + \frac{N_{Pb}(125^0)}{\varepsilon_{Pb} \cdot \Delta\Omega_{Pb}} = 2F \cdot S \cdot n_{Pb} \cdot \frac{\sigma_{Pb}}{4\pi}. \tag{5}$$

From relation (5) it is possible to find the F·S value. Then for arbitrary θ the differential cross sections of neutron scattering by ^{208}Pb nuclei may be determined with the following expression (measurements are conducted with the same detector):

$$\sigma'_{Pb} = \frac{2N_{Pb}(\theta)}{N_{Pb}(55^0) + N_{Pb}(125^0)} \cdot \frac{\sigma_{Pb}}{4\pi}. \tag{6}$$

For the investigated sample the measurements on which are conducted in one experiment with the standard one and the same detector, the differential cross sections of neutron scattering in LS is calculated with formula:

$$\sigma'_x(\theta) = \frac{2N_x(\theta) \cdot \varepsilon_{Pb}}{\varepsilon_x\left[N_{Pb}(55^0) + N_{Pb}(125^0)\right]} \cdot \frac{\sigma_{Pb}}{4\pi} \cdot \frac{n_{Pb}}{n_x}. \tag{7}$$

It is necessary to keep in mind that with this formula the differential cross section of neutron scattering by the investigated sample nuclei is calculated, when there is no necessity to determine the differential cross section of scattering by standard ^{208}Pb.

At the relative measurements of differential cross section of scattering by investigated sample nuclei with the multi-detector system, in the experiment a value $\frac{N_x(\theta)}{N_{Pb}(\theta)} \equiv k(\theta)$ can be received for each angle, where detector is set on. For these angles the differential cross sections are calculated with the following formula

$$\sigma'_x(\theta) = \frac{k(\theta) \cdot \sigma'_{Pb}(\theta) \cdot n_{Pb}}{n_x} \cdot \frac{\varepsilon_{Pb}(\theta)}{\varepsilon_x(\theta)}. \tag{8}$$

The special role of relation $\frac{\varepsilon_{Pb}(\theta)}{\varepsilon_x(\theta)}$ follows from above. In connection with this, the mathematical model of angular distribution measurements for the scattering neutrons was developed and the proper programs of calculations were created for efficiency of registration of the neutrons scattered by investigated samples and standard.

6. Experimental differential cross sections of neutron scattering by ^{208}Pb and carbon nuclei at energy 2 keV and analysis of results.

For illustration of installation operation we present some results of the relative angular measurements received at IASD-1 at 2 keV average energy of quasi-monochromatic neutrons, though the investigations were done at other energies too.

The neutron beam with the indicated energy was received after filter with such components: Sc, Ti, Co and ^{10}B. The scattered neutrons were registered by detector assemblies on the base of the CHM-17 counters. Measurements on every investigated sample were conducted in accordance with the measurement cycle discussed in the second part of this article. The following spectrums of the scattered neutrons were measured in the experiments: on the sample - $N_i(n)$, on the sample when the beam was screened by polyethylene - $PE_i(n)$, on a standard - $N_{Pb}(n)$, on a standard and beam screened by polyethylene - $PE_{Pb}(n)$, on the holder of sample – N_0 (n) and on a holder at the screened beam – PE_0(n). At treatment, definite areas in neutron part of experimental spectrums and the sums of counts were calculated (^{3}He counters), from which the values of effects were calculated for each of the samples in accordance with equations:

for the sample - $N_i = \sum N_i(n) - \sum PE_i(n)$,

for standard - $N_{Pb} = \sum N_{Pb}(n) - \sum PE_{Pb}(n)$,

for the holder - $N_0 = \sum N_0(n) - \sum PE_0(n)$.

In all these equations a sum is received within the limits of the chosen channels (identical for all spectrums) in neutron part of experimental spectrums.

Then, in accordance with the part five of this article, the following experimental value may be defined

$$\frac{N_x(\theta)}{N_{Pb}(\theta)} \equiv k(\theta) = \frac{N_i - N_0}{N_{Pb} - N_0}.$$

Further, the calculations of differential cross section of neutron scattering by nuclei of the investigated samples were conducted with formulas (6) - (8).

With the purpose of working off the method of measurements and algorithm of treatment for the experimental results of differential scattering cross section, the measurements were begun on the samples of carbon, which is used enough often as a standard in different nuclear-physics experiments. For measurements there were used the standards of a different thickness from powder of reactor graphite and the pressed disks with 1mm thickness, booked in England (Goodfellow Company).

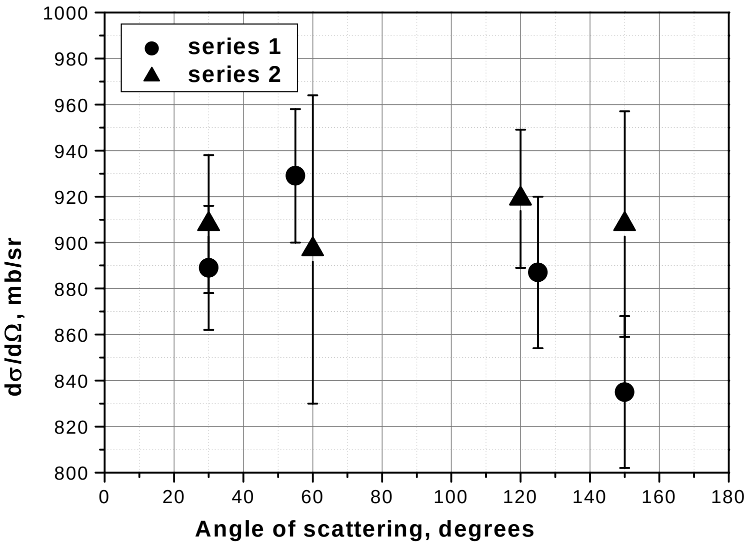

Fig. 6. Differential scattering cross section for ^{208}Pb.

The measurements on a standard ^{208}Pb preceded to measurements on the carbon samples. Two series of differential cross section measurements were conducted on this standard. The results of two series of measurements on ^{208}Pb are presented in Fig. 6. Treatment of experimental results was executed with formula (6).

The first series is the measurement of the angular distribution with one neutron detector, which was moved to the fixed angle of scattering. For these values a statistical error is presented. The second series of measurements was conducted with four detectors; each of them by turns was fixed under the definite angle of scattering. An inaccuracy for these data corresponds root-mean-square deviation of four measurements from the mean value.

In Fig. 6 the value for angle 90° is not presented. It is related with that the response function of detector for this angle diminishes as compared to the neighbor angles in obedience to experimental information only on 10 %, at that time the calculations of efficiency with the program give the reduction about 30 % at the enough good agreement for other angles. The reason of this effect is not clear. Possibly, it is conditioned by some lacks in experiment geometry (non-perpendicularity of sample plane to axis of neutron beam, and there are three samples and each can have the different deviation from perpendicularity). Influence of these factors is the most just for the angle 90°.

Coming from obtained data, it is possible to allege that for marked angles in the Table the differential cross sections of neutron scattering on ^{208}Pb at energy 2 keV is isotropic with the inaccuracy 3 - 5 %.

In Fig. 7 the experimental differential cross sections of neutron scattering are presented for 6 carbon (graphite) samples of a different thickness in LS. Data for the angles 55, 60° and 120, 125° are joined. The re-calculation of cross section for a carbon in CM shows on the isotropic scattering of neutrons in this co-ordinates system.

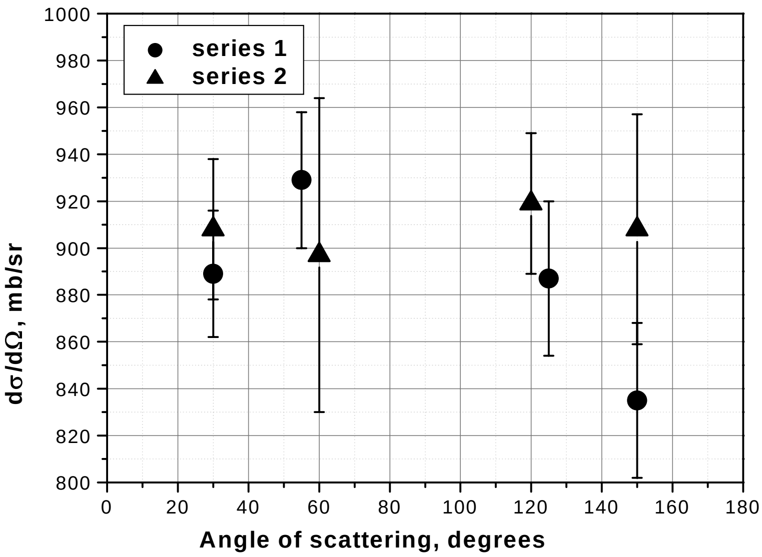

Fig. 7. Differential scattering cross section for carbon averaged over six samples.

7. Conclusion

The conducted experiments showed:

1) the possibility of measurements at the filtered neutron beams of differential scattering neutron cross sections (even, at energies in a few keV),

2) the necessity to reduce the distance between the experimental installation input and output of reactor channel for providing of sufficient intensity of neutron beam at the sample when the filters with insufficient intensity of neutrons at the output are used,

3) the necessity to improve the experimental installations with the purpose to provide the assured perpendicularity of the explored sample surface to the axis of beam during measurement,

4) the necessity of obligatory monitoring of neutron beam in the process of measurements.

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ЭКСПЕРИМЕНТАЛЬНЫЕ УСТАНОВКИ ДЛЯ ИССЛЕДОВАНИЯ УГЛОВЫХ РАСПРЕДЕЛЕНИЙ РАССЕЯНИЯ НЕЙТРОНОВ

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Описаны две экспериментальные установки УКР-1 и УКР-2 для измерений угловых распределений квазимоноэнергетических нейтронов, рассеянных исследуемыми образцами. Основой каждой установки является вакуумная цилиндрическая камера, по середине которой расположен электромеханический узел для автоматической перестановки образцов-рассеивателей. Нейтронный пучок подводится к образцу и отводится от него через закрытые тонкими алюминиевыми диафрагмами отрезки труб. Обе установки имеют одинаковые электронные измерительные тракты. При измерениях управление установками осуществляется специальной программой ZERKIN-3. Измерения угловых распределений относительны. В качестве стандарта используется ^{208}Pb. Фоновые спектры измеряют при перекрытом полиэтиленом нейтронном пучке. Установка УКР-1 позволяет проводить измерения под любыми углами в диапазоне 30 - 150°. Регистрация рассеянных нейтронов осуществляется четырьмя детекторными сборками. Каждая сборка состоит из семи гелиевых счетчиков СНМ-17, которые работают на один предварительный усилитель. Сборки имеют индивидуальную радиационную защиту. Установка УКР-2 рассчитана на измерения спектров под фиксированными углами 55, 90, 125, 150 и 165°. Для регистрации нейтронов используются счетчики LND-2527 и LND-281, которые располагаются в общей радиационной защите из карбида бора. Кроме того, могут использоваться упомянутые выше детекторные сборки из СНМ-17.

ЕКСПЕРИМЕНТАЛЬНІ УСТАНОВКИ ДЛЯ ДОСЛІДЖЕННЯ КУТОВИХ РОЗПОДІЛІВ РОЗСІЯННЯ НЕЙТРОНІВ

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Описано дві експериментальні установки УКР-1 і УКР-2 для вимірювання кутових розподілів квазімоноенергетичних нейтронів, розсіяних дослідними зразками. Основою кожної з установок є вакуумна циліндрична камера, у середині якої розміщено електромеханічний вузол для автоматичної перестановки зразків-розсіювачів. Нейтронний пучок підводиться до зразка і відводиться від нього через закриті тонкими алюмінієвими діафрагмами відрізки труб. Обидві установки мають однакові електронні вимірювальні тракти. При вимірюваннях керування установками відбувається спеціальною програмою ZERKIN-3. Вимірювання кутових розподілів відносні. В якості стандарту використовується зразок ^{208}Pb. Фонові спектри вимірюють при перекритому поліетиленом нейтронному пучку. Установка УКР-1 дозволяє проводити вимірювання під будь-якими кутами в діапазоні 30 - 150°. Реєстрація розсіяних нейтронів відбувається одночасно чотирма детекторними збірками. Кожна збірка складається з семи гелієвих лічильників СНМ-17, що працюють на один попередній підсилювач. Збірки мають індивідуальний радіаційний захист. Установка УКР-2 розрахована на вимірювання спектрів під фіксованими кутами 15, 30, 55, 90, 125, 150 та 165°. Для реєстрації нейтронів використовують лічильники LND-2527 та LND-281, які розміщують у спільному радіаційному захисті з карбіду бора. Крім того можуть бути використані згадані вище детекторні збірки із СНМ-17.