SOVIET PHYSICS
JETP

A translation of the Zhurnal Éksperimental'noĭ i Teoreticheskoĭ Fiziki.

Vol. 14, No. 2, pp 225-483 (Russ. orig. Vol. 41, No. 2, pp 313-669, August, 1961) February, 1962

ANGULAR DISTRIBUTIONS FOR ELASTIC SCATTERING OF 14-Mev NEUTRONS

V. I. STRIZHAK, V. V. BOBYR', L. Ya. GRONA

Physics Institute, Academy of Sciences, Ukrainian S.S.R.

Submitted to JETP editor January 9, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 313-316 (August, 1961)

We have measured the differential cross section for elastic scattering of 14-Mev neutrons from carbon, nitrogen and silver at angles from 20 to 140° and from molybdenum, cadmium, and tellurium at angles from 15 to 160°. After some necessary corrections have been made, the experimental data are compared with cross sections calculated on the basis of the optical model of the nucleus.

THERE are many experimental data which are well accounted for by the optical model of the nucleus, particularly by the more recent modifications of this model.[1-4] This is especially true of cross sections for the elastic scattering of neutrons at an energy of 14 Mev.[5-19]

The purpose of the present paper is to present experimental results on the differential cross section for elastic scattering of 14-Mev neutrons by carbon, nitrogen, sulfur, molybdenum, cadmium, and tellurium.

The measurements were made on toroidal scatterers.

The 14-Mev neutrons were produced by bombarding a T-Zr target with 120-kev deuterons in the neutron generator of the Physics Institute of the Academy of Sciences of the Ukrainian S.S.R.[18]

A scintillation counter was used to detect neutrons from molybdenum, cadmium, and tellurium. The counter was sensitive only to neutrons having energy greater than a threshold of 11 Mev. This threshold was not high enough to discriminate completely against inelastically scattered neutrons, and this effect was significant at large angles. However, a higher threshold could not be used partly because a lower counting rate would lead to larger statistical errors and also because of instabilities in the electronic circuitry.

Neutrons scattered from carbon, nitrogen, and sulfur were detected with a scintillation spectrometer using a stilbene crystal and an FÉU-14A photomultiplier. Pulses from the photomultiplier were fed to an AI-100-1 amplitude analyzer. The resolution of the spectrometer was 3% (400 kev). The neutron spectra obtained made it possible to distinguish reliably between elastic and inelastic scattering events.

We measured the relative sensitivity $A(\alpha)$ of the neutron detector as a function of the direction of flight of the incident neutrons.

The scatterers were rings of diameter 13, 20, 25 and 30 cm. The cross-section diameters of the rings were 2 cm for carbon, 3 cm for cadmium, molybdenum, and tellurium, and 4 cm for nitrogen and sulfur.

In the case of nitrogen, the scatterer was made by filling a toroidal Dewar flask with liquid nitrogen. The flask walls were made of 0.5 mm copper.

The measurements were normalized by using scintillation counters to monitor neutrons and α particles from the $T(d, n)\alpha$ reaction.

The differential cross section $\sigma_{el}(\vartheta)$ for elastic scattering was computed from the experimentally measured values of the quantity

$$S(\vartheta) = (N_{sc} - N_b) / N_d, \qquad (1)$$

where N_{sc} is the number of counts with the scatterer and shield in, N_b is the number of counts without the scatterer (background), and N_d is the number of counts without the scatterer and without the shield.

The differential cross section for elastic scattering through an angle ϑ was calculated from the formula

$$\sigma_{el}(\vartheta) = S(\vartheta)(R_1 R_2 / R_0)^2 \exp(n\sigma_{in} d) / NA(\alpha) B(E_n), \qquad (2)$$

where R_1 is the distance from the source to the scatterer, R_2 is the distance from the scatterer to the detector, and R_0 is the distance from the source to the detector. n is the number of nuclei per cc in the scatterer, σ_{in} is the cross section for inelastic scattering, d is the thickness of the scatterer, N is the number of scattering nuclei, and $B(E_n)$ is a correction factor to account for the dependence of the detector sensitivity on energy.

No correction was made for multiple scattering, although it may be considered that these effects are partially accounted for by using σ_{in} in formula (2) instead of the total cross section σ_t.

The measurements did not take long, so that drift in the electronics was not important. For angles less than 70°, statistical errors were less than 4%, while for larger angles these amounted to 7 or 8%.

Measurements were made for angles in the range 20 — 40° for carbon, nitrogen and sulfur, and in the range 15 — 160° for molybdenum, cadmium, and tellurium. The results are shown in Figs. 1 — 6. The solid curves are theoretical, being calculated using the optical model.

Our data agree well with the results of other authors: for carbon, Anderson et al[19]; for nitrogen, Hughes[16]; for sulfur, Elliot[9] and St. Pierre et al[15]; for cadmium (at large angles), Anderson et al.[12]

For carbon, sulfur, molybdenum, cadmium, and tellurium the experimental data are compared with calculations based on the potential given by Bjorklund and Fernbach (Fig. 1, solid curve). There are no theoretical curves for scattering from molybdenum and tellurium, so the data have been compared with existing calculations for the neighboring nuclei zirconium and antimony.

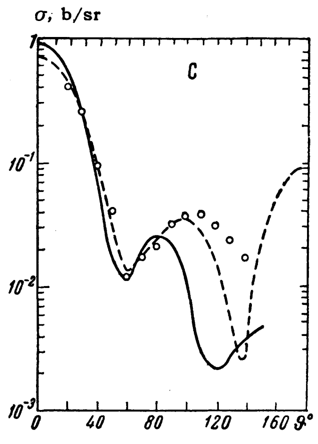

FIG. 1. Differential cross section for the elastic scattering of 14-Mev neutrons on carbon (in the laboratory frame of reference). Theoretical curves: the solid line in this and the following figures is taken from Bjorklund and Fernbach, the dashed line from Beister et al.[16]

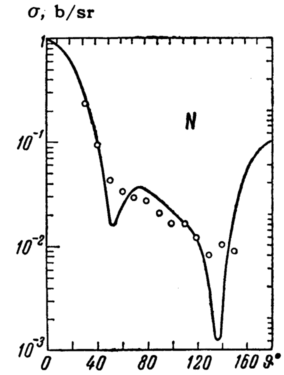

FIG. 2. Differential cross section from elastic scattering on nitrogen.

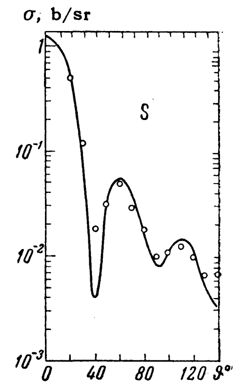

FIG. 3. Differential cross section for elastic scattering on sulfur.

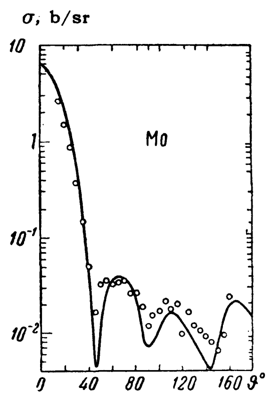

FIG. 4. Differential cross section for elastic scattering on molybdenum.

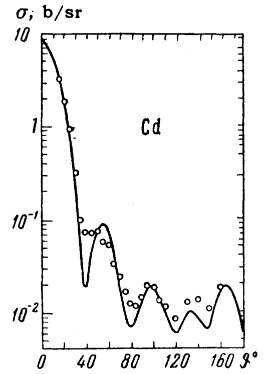

FIG. 5. Differential cross section for elastic scattering on cadmium.

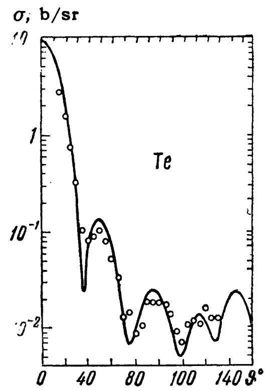

FIG. 6. Differential cross section for elastic scattering on tellurium.

The theoretical curves calculated by Bjorklund and Fernbach are in good agreement with the experimental data for sulfur, molybdenum, cadmium, and tellurium. The calculations disagree with experiment for carbon. Better agreement is obtained by comparing the experimental data with the curve calculated by Beister et al[16] (and shown as the dashed curve in Fig. 1).

[1] Culler, Fernbach, and Sherman, Phys. Rev. **101**, 1047 (1956).

[2] Bjorklund, Fernbach, and Sherman, Phys. Rev. **101**, 1832 (1956).

[3] F. Bjorklund and S. Fernbach, Phys. Rev. **109**, 1295 (1958).

[4] Luk'yanov, Orlov, and Turovtsev, JETP **35**, 750 (1958), Soviet Phys. JETP **8**, 521 (1959).

[5] J. P. Conner, Phys. Rev. **89**, 712 (1953).

[6] J. R. Smith, Phys. Rev. **95**, 730 (1954).

[7] W. J. Rhein, Phys. Rev. **98**, 1300 (1955).

[8] M. M. Khaletskii, DAN SSSR **113**, 305 (1957), Soviet Phys. Dokl. **2**, 129 (1958).

[9] J. O. Elliot, Phys. Rev. **101**, 684 (1956).

[10] H. Nauta, Nucl. Phys. **2**, 124 (1956).

[11] Berko, Whitehead, and Groseclose, Nucl. Phys. **6**, 210 (1958).

[12] Nakada, Anderson, Gardner, and Wong, Phys. Rev. **110**, 1439 (1958).

[13] Coon, Davis, Felthauser, and Nicodemus, Phys. Rev. **111**, 250 (1958).

[14] K. Yuasa, J. Phys. Soc. Japan **13**, 1248 (1958).

[15] St. Pierre, Machwe, and Lorrain, Phys. Rev. **115**, 999 (1959).

[16] D. Hughes, Proc. Second International Conference on the Peaceful Uses of Atomic Energy, Neutron Physics, p. 39 (1959).

[17] L. A. Rayburn, Phys. Rev. **116**, 1571 (1959).

[18] Bobyr', Grona, and Strizhak, JETP **41**, 24 (1961), Soviet Phys. **14**, 18 (1962).

[19] V. I. Strizhak and N. S. Nazarov, Pribory i Tekhnika Éksperimenta (Instrum. and Exptl. Techniques), in press.

[20] Anderson, Gardner, McClure, Nakada, and Wong, Phys. Rev. **111**, 572 (1958).

Translated by R. Krotkov
63