Reports of the Academy of Sciences of the USSR

G. V. GORLOV, N. S. LEBEDEVA, V. M. MOROZOV

1964

SovietRxiv

Abstract

Full Text

Reports of the Academy of Sciences of the USSR
1964. Volume 158, No. 3

PHYSICS

G. V. GORLOV, N. S. LEBEDEVA, V. M. MOROZOV

ELASTIC SCATTERING OF POLARIZED NEUTRONS BY NUCLEI OF

Be^9, C^{12}, Co^{59}, Ni^{62}, Se^{80}, Nb^{93}, Cd^{114}, In^{115}, Sn^{118}, J^{127}, Pb, and Bi^{209}

(Presented by Academician A. P. Aleksandrov, 16 IV 1964)

An experimental study of the elastic scattering of polarized neutrons by various nuclei is of interest for determining the values of the parameters of the optical model of the nucleus. In the present work we briefly set forth the principal experimental results of an investigation of the elastic scattering of polarized neutrons with energy 4.00 ± 0.05 MeV. The differential cross sections of elastic scattering were measured in the plane perpendicular to the direction of the neutron polarization vector, over the range of scattering angles from 10 to 170° to the right and to the left of the direction of the beam of scattered neutrons. The measurements were made every 10° with a resolution (root-mean-square deviation from the nominal value of the measurement angle) equal to 4°.

Most of the elements investigated had a practically single-isotope composition; a number of elements were used in the form of specimens substantially enriched in one of the isotopes: Ni^{62} (86%), Se^{80} (94%), Cd^{114} (94%), and Sn^{118} (73%); only lead was represented by a natural mixture of isotopes.

As a source of polarized neutrons the $d(d,n)He^3$ reaction was used ($E_d = 1200 \pm 50$ keV). The neutrons, emitted from a gas target at an angle of 37° to the direction of the deuteron beam (in the laboratory system of reference), were collimated by a wedge-shaped paraffin–lead collimator and scattered by cylindrical samples with diameters of 20–25 mm and a height of about 60 mm (the larger diameters were those of samples pressed from powders). The scattered neutrons were detected by six scintillation counters (stilbene crystals with FEU-33 photomultipliers), arranged in pairs symmetrically with respect to the beam of scattered neutrons. The energy spectra of the scattered neutrons were determined from the pulse spectra of the photomultipliers, analyzed by six-channel amplitude analyzers. Background counts from γ rays were eliminated by separating the neutron counts according to the shape of the scintillation pulse ([1]);

Fig. 1

Figure 1: Fig. 1

practically complete elimination of this background was achieved. The background of neutrons scattered by parts of the apparatus and by the walls of the measuring room was reduced by means of a massive shield made of blocks of paraffin with boron. The remaining neutron background was very stable and therefore interfered with the measurements comparatively little. At the minima of the differential cross sections the relative magnitude of the background reached 50% of the total number of counts in the presence of the scattering sample, and only in the region of large scattering angles, because of the proximity of the detectors to the exit aperture of the collimator, did the neutron background increase to 80% of the total number of counts. Since the neutron background was not modulated by the samples, the fluxes of neutrons scattered by the samples were determined as the differences between the detector counts in measurements with the scattering samples in the neutron beam and in measurements without scattering samples.

The fluxes of neutrons scattered inelastically with an energy loss of not less than 1 MeV were determined for each sample and excluded from the measurement result, under the assumption of isotropy of the differential cross sections of inelastic ···

elastic scattering from the spectra of scattered neutrons in the angular range from 50 to 150°.

Corrections for the displacement of the effective center of neutron scattering by the samples relative to the geometrical centers (maximum corrections of the order of 4%) were also introduced into the relative differential cross sections of elastic neutron scattering obtained after subtracting the background of neutrons inelastically scattered by the samples.

Fig. 1

The comparatively high transmissions of the samples (from 0.7 to 0.8) made it possible to introduce corrections for multiple scattering of neutrons in the samples in a sufficiently simple way; this correction proved to be significant only in the minima of the differential cross sections, where it sometimes reached 20% of the experimental result, while in the majority of cases the correction was comparable with the relative error of the measurements, which in turn for most experimental points

was within the range from 1 to 6% (with the exception of the points at 170° and some others, where the accuracy was lower).

The differential cross sections for elastic scattering of unpolarized neutrons (the half-sum of the neutron scattering cross sections at the corresponding angles to the right and to the left of the direction of the scattered-neutron beam) are

Fig. 2

Figure 2: Fig. 2

shown in Fig. 1. Errors in determining the relative behavior of the differential cross sections are shown in the graphs only for those points for which the relative errors exceed 4%. Errors in determining the absolute differential cross sections reach 5%.

Fig. 2

The asymmetry of the differential cross sections for elastic scattering of neutrons to the right and to the left was used to determine the polarizing power of the nuclei. In doing so it was assumed that the most probable value of the polarization of neutrons from the $d(d,n)He^3$ reaction under the experimental conditions, in accordance with review ([2]), is -0.14. The results are shown in Fig. 2 (the sign of the polarization is indicated in accordance with the "Basel convention"). The errors in determining the polarizing power of the nuclei are due mainly to statistical errors in the measurements of the differential cross sections; the effect of precisely these errors is enhanced because of the low degree of polarization of the neutrons used in the experiment.

It should be noted that the differential cross sections for elastic neutron scattering and the polarizing powers of the nuclei were measured in the experiment without separation into components corresponding to elastic scattering without formation of a compound nucleus and to elastic scattering through a compound nucleus. This must be taken into account when comparing the experimental results with the conclusions of the optical model of the nucleus. One may hope, however, that under the conditions of this experiment, for the majority of nuclei the contribution of elastic scattering through a compound nucleus is small.

The dependence of the differential cross sections on the scattering angle for most nuclei reveals a typical "diffraction" character and a smooth-

but changes with the change in atomic weight: the positions of the maxima and minima of the cross sections are regularly shifted toward smaller angles with increasing A. For nuclei with similar A, the behavior of the differential cross sections is similar (see, for example, Cd^{114}, In^{115}, and Sn^{118}); only for Co^{59} and Ni^{62} is a significant difference observed in the behavior of the differential cross sections in the region of large scattering angles. It is interesting to note the increase in the differential scattering cross sections at large angles for the nuclei Se^{80}, Nb^{93}, Pb, and Bi^{209}.

The significant values of the polarizing power of nuclei found experimentally show that the spin-orbit interaction plays an essential role in the process of elastic neutron scattering at the energy used in the experiment. The dependence of the polarizing power of nuclei on the scattering angle reveals a complex character: the polarizing power of nuclei changes sign more than once, reaching, in absolute value, 50% or more for most nuclei. In work ([3]) a definite assumption was made about the nature of the relationship between the behavior of the differential cross sections and the polarizing power of nuclei as a function of the scattering angle. In particular, the polarizing power of nuclei should vanish at the maxima and minima of the differential cross sections. Apparently, such a relationship is not realized literally, since in many cases the zeros of the polarizing power of nuclei do not coincide exactly with the maxima and minima of the differential cross sections. However, a certain correlation is found between the differential cross sections and the polarizing powers of nuclei, which may perhaps be expressed by the weaker statement: the number of passages of the nuclear polarizing power through zero is equal to the number of extrema of the differential scattering cross section of unpolarized neutrons.

Institute of Atomic Energy
named after I. V. Kurchatov
Academy of Sciences of the USSR

Received
7 IV 1964

REFERENCES

1. V. G. Brovchenko, G. V. Gorlov, *Instruments and Experimental Techniques*, No. 4, 49 (1961).

2. W. Haeberli, *Progress in Fast Neutron Physics*, 1963, p. 307.

3. L. S. Rodberg, *Nucl. Phys.*, **15**, 72 (1960).

Note: Figure translations are in progress. See original paper for figures.