ANGULAR DISTRIBUTION OF ELASTICALLY AND INELASTICALLY SCATTERED 2.9-MeV NEUTRONS

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A hydrogen ionization chamber and annular geometry are used to measure the angular distribution of elastically and inelastically scattered 2.9-MeV neutrons, as well as inelastically scattered neutrons associated with excitation of various levels or groups of levels of iron, copper, lead, and bismuth nuclei. The integral cross sections for elastic and inelastic scattering are presented, as are the transport cross sections. The experimental results are compared with theoretical calculations based on the optical model. It is noted that the angular distribution of elastically scattered neutrons from atoms with almost equal atomic weights may be quite different.

INTRODUCTION

Much attention has been paid of late to the study of angular distributions and spectra of scattered neutrons. The results of such experiments are very important to the understanding of the mechanism of nuclear reactions and nuclear structure. From an analysis of the angular distributions of inelastically scattered neutrons under conditions in which the statistical theory is applicable to the compound nucleus, one can determine the spins and parities of the final nucleus [1]. Data on the angular distribution of elastically and inelastically scattered neutrons can be used to verify the validity of various nuclear models and to indicate directions for their further refinement. Finally, all these experimental data are used in reactor calculations.

The purpose of the present work was to obtain data on the angular distribution of scattered monochromatic neutrons whose energy is 2.9 MeV while simultaneously measuring their spectra.

Method of Measurement and Apparatus

The angular distributions of the scattered neutrons were measured with an annular geometry (Fig. 1), and the scattering angle was varied by moving the ring and detector in the horizontal direction. The neutron source was a target of heavy ice bombarded by deuterons accelerated to an energy of 150 kev. The mean energy of the neutrons incident on the scatterer was 2.9 ± 0.1 Mev. The neutron detector was a spherical ionization chamber (Fig. 2) with an external electrode diameter of 13 cm, filled with a mixture of 5 atmos of hydrogen and 5 atmos of argon; this ionization chamber registered recoil protons. The spherical shape of the chamber minimizes the undesirable induction effect, which would otherwise alter the pulse spectrum of the recoil protons; in addition, this shape leads to an efficiency which is practically independent of the incident neutron direction. To aid electron collection, the gases were subjected to a preliminary purification of electronegative impurities by passing them through copper wool heated to 500°C and by adsorption on activated carbon at liquid nitrogen temperatures. In several cases the chamber was further purified, irradiating it by γ-rays while a potential was maintained on the electrodes.

An especially constructed insulator (in the form of a guard ring) permitted operation of the chamber at a potential difference of 12 kv, which was necessary for complete charge collection.

In chambers of this type the fundamental factors altering the pulse spectrum are the wall effect and the induction effect [2]. Calculation shows that the pulse spectrum of the chamber, when it is irradiated by monochromatic neutrons of energies up to 3 Mev, should be of the form
The pulse spectrum given by this equation is approximately a trapezoid with rounded-off corners (Fig. 3), and whose bases are in the ratio

\[
\frac{b}{a} = \frac{R_{cp} + \lambda(E_0)}{R_{cp} - \lambda(E_0)}. \]

Over a large section, the measured chamber pulse spectrum (Fig. 4) can also be approximated by a trapezoid, but with a larger ratio of the bases than that given by the formula. This would seem to be due to other factors not accounted for. Therefore, the actual calculation of the intensity of neutron groups was performed on the basis of the following formula, obtained from the previous one by introducing the two constant coefficients \(\alpha_1\) and \(\alpha_2\):

\[
\frac{b}{a} = \frac{R_{cp} + \alpha_1\lambda(E_0)}{R_{cp} - \alpha_2\lambda(E_0)}.
\]