E3-93-466

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SYSTEMATICAL ANALYSIS OF THE FAST NEUTRON INDUCED (*n*, *p*) REACTION CROSS SECTIONS

1993

Introduction

Investigation of the fast neutron induced (n,p) reaction cross section is of interest to studies of reaction mechanisms and nuclear structure. On the other hand, the (n,p) reaction is important in reactor design technology, in particular for estimations of nuclear heating, radiation damage and induced activity in structural materials. Because of these, it would be very useful to derive some empirical law governing (n,p) cross section variation. Several formulae have been suggested to describe the dependence of the (n,p) reaction cross section upon the asymmetry parameter (N-Z)/A of neutron and proton numbers in the target nucleus around the neutron energy of 14.5 MeV [1-4]. Recently, we observed a similar dependence for the (n,p) cross section, averaged over the fission spectrum of ^{235}U, using thermal neutrons [5].

In this paper we report on the attempt to make a systematic analysis for the known (n,p) cross sections in a wider energy range, namely, at energies of 6, 8, 10, 14.5 and 16 MeV.

Formulae and Data Analysis

The (n,p) reaction cross section at the neutron energy around 14.5 MeV is satisfactorily described by the formula referred in literature as the isotopic effect:

$$\sigma_{np} = C\pi r_0^2(1 + A^{\frac{1}{3}})^2 \exp[\frac{-K(N-Z)}{A}] \qquad (1)$$

where $r_0 = 1.4 \cdot 10^{-13}$ cm; A, N, and Z are the mass number, number of neutrons, and charge of the target nucleus, respectively; C and K are the fitting parameters. Analysis based on the experimental results at 14.5 MeV published up to 1972 showed that C≈0.73 and K≈33 [1]. Furthermore, it was found that the parameter C≈0.73 is approximately the ratio of the (n,p) cross section to the sum of the (n,p) and (n,α) cross sections.

Now, we shall use a formula of type (1) to describe the (n,p) cross section for the energy range of 6 to 16 MeV. At energies below 10 MeV the approximation C=1 can be used, as in the case of the thermal fission spectrum of ^{235}U [5], because for energies $E_n \leq 10$ MeV, the (n,α) cross section is, as a rule, too small in comparison with (n,p) cross section and can be neglected. Then, formula (1) can be rewritten in the form:

$$\sigma_{np} = \pi r_0^2 (1 + A^{\frac{1}{3}})^2 \exp[\frac{-K(N-Z)}{A}]. \tag{2}$$

Thus, using formula (2) for energies $E_n \leq 10$ MeV we must obtain only the fitting parameter K.

Figs. 1, 2 and 3 show experimental values of (n,p) cross sections taken from compilation [6] and the line fitted by expression (2) at energies of 6, 8 and 10 MeV, respectively. Plus and minus symbols denote the positive and negative Q-values, respectively. Corresponding values of the fitting parameter K are also given in these figures.

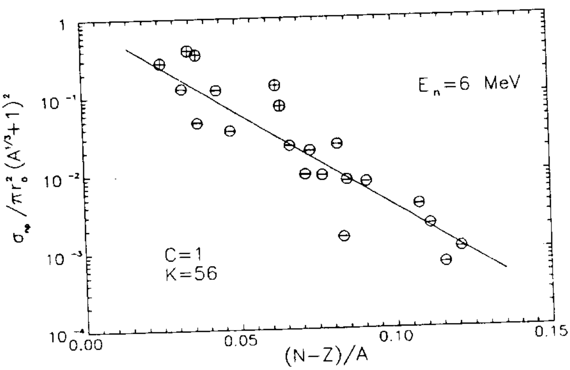

Figure 1. The dependence of reduced (n,p) cross sections on the asymmetry parameter (N-Z)/A of neutron and proton numbers in the target nucleus at E_n=6 MeV.

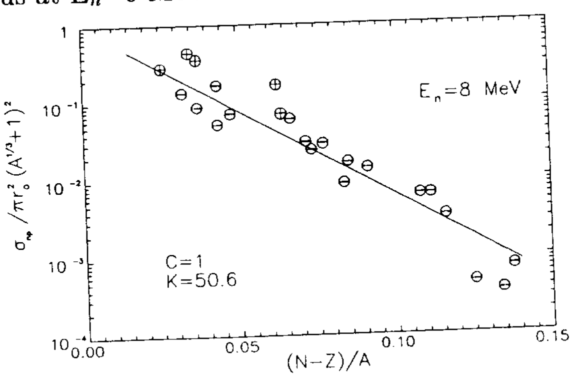

Figure 2. The same as in Fig.1 at E_n=8 MeV.

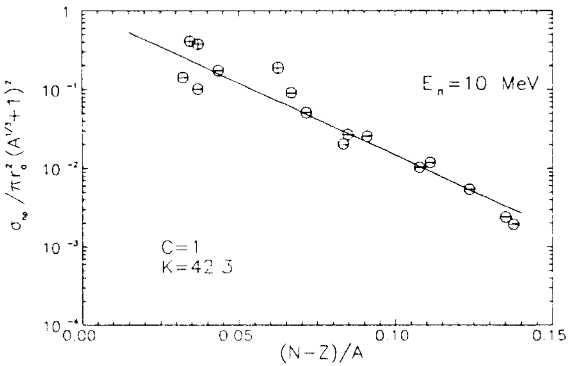

Figure 3. The same as in Fig.1 at E_n=10 MeV.

Regarding the energies of 14.5 and 16 MeV, we used formula (1) because the (n,α) cross section in these cases is not small enough in comparison with (n,p) cross section to be ignored and should be taken into account in our calculations. Figs. 4 and 5 show experimental data of (n,p) cross sections taken from ref. [6] and the line fitted by formula (1) at the energies of 14.5 and 16 MeV, respectively. In these figures, the corresponding values of the fitting coefficients C and K are given.

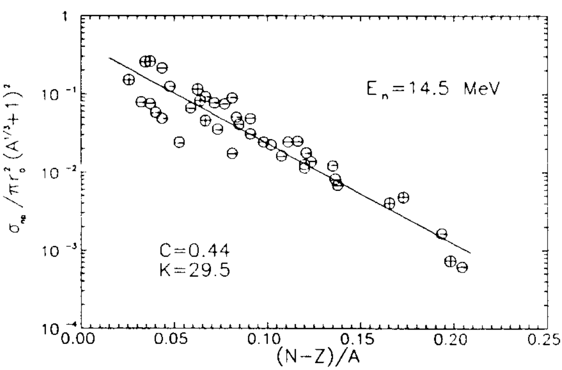

Figure 4. The same as in Fig.1 at E_n=14.5 MeV.

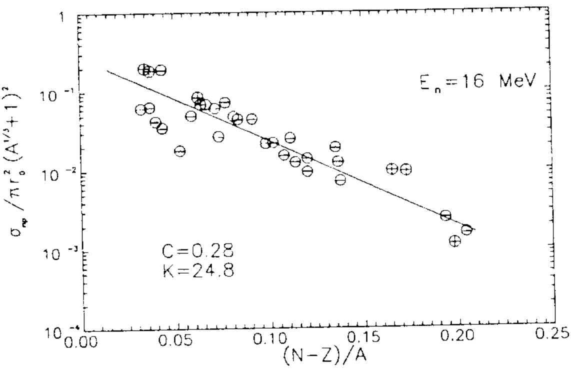

Figure 5. The same as in Fig.1 at E_n=16 MeV.

Figs. 1-5 demonstrate that formulae of type (1) satisfactorily describe the dependence of known experimental (n,p) cross sections on the asymmetry parameter (N-Z)/A of the neutron and proton numbers in the target nucleus for the wide energy range of 6 to 16 MeV. For such a systematic analysis, perhaps some correction should be made to the Q-value of the (n,p) reaction, in particular, for $E_n \leq 10$ MeV. In these cases the Q-value is frequently not small enough in comparison with the neutron energy to be ignored. Further it is necessary to study such behavior of the (n,p) cross sections from the view-point of nuclear reaction mechanisms and nuclear structure theory.

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Received by Publishing Department
on December 28, 1993.

Хуухэнхуу Г. и др. E3-93-466

Систематический анализ сечений реакции (n, p), вызываемой быстрыми нейтронами

Проведен систематический анализ существующих экспериментальных сечений реакции (n, p), вызываемой быстрыми нейтронами, для широкого круга ядер. Получена зависимость сечений реакции (n, p) от параметра асимметрии протон-нейтронного числа ядра-мишени $(N - Z)/A$ при энергиях нейтронов 6, 8, 10, 14,5 и 16 МэВ.

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

Сообщение Объединенного института ядерных исследований. Дубна, 1993

Khuukhenkhuu G. et al. E3-93-466

Systematical Analysis of the Fast Neutron Induced (n, p) Reaction Cross Sections

Systematic analysis of known experimental cross sections of the (n, p) reaction induced by fast neutrons was carried out for a wide range of nuclei. The dependence of the (n, p) cross sections on the asymmetry parameter $(N - Z)/A$ of proton and neutron numbers in the target nucleus was obtained for neutron energies of 6, 8, 10, 14.5 and 16 MeV.

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

Communication of the Joint Institute for Nuclear Research. Dubna, 1993

6 р.

Макет Т.Е.Попеко

Подписано в печать 22.12.93
Формат 60x90/16. Офсетная печать. Уч.-изд. листов 0,5
Тираж 325. Заказ 46918

Издательский отдел Объединенного института ядерных исследований
Дубна Московской области