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CROSS SECTIONS FOR THE REACTIONS $^{141}Pr(n, p)^{141}Ce$, $^{141}Pr(n, t)^{139}Ce$, $^{142}Ce(n,2n)^{141}Ce$ AND $^{140}Ce(n,2n)^{139}Ce$

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I. Introduction

Different trends have been observed in the data for neutron reaction cross sections vs. neutron, proton or mass number, in the energy region about 14 MeV /1,2,3/. It is desirable to have larger as well as more accurate data in order to check these trends, especially for nuclei near closed shells. It is also important to examine the applicability of the empirical cross section formulae /1,4,5/ based on these trends, by new measurements. In many cases the activation cross sections could not be determined because of the unfavourable properties of the residual nuclei. The high resolving power of the Ge(Li) detector renders it possible to obtain some of the data undetermined so far, and to improve the accuracy of those already known. By use of this technique, at 14.8 MeV neutron energy we have measured the cross sections for the (n, p), (n, t) and (n, 2n) reactions leading to the residual nuclei ^{139}Ce and ^{141}Ce.

II. Experimental Procedure

100 mg CeO_2 and 100 mg Pr_6O_{11} powders were irradiated by

14.8 MeV neutrons. The neutrons were obtained from the $^{3}H(d,n)^{4}He$ reaction, using the 300 kV cascade generator of the ATOMKI. The samples were irradiated for 63 hours by a flux of $\approx 10^{10}$ neutrons $cm^{-2} \cdot sec^{-1}$. The flux was monitored continually by a $^{10}BF_3$ long counter and a plastic scintillator. The activities of the irradiated samples were measured by a Ge (Li) spectrometer /6/, without spectrum stabilisation. The Ge (Li) spectrometer was calibrated by an ^{169}Yb source. The measurement began 120 hours after the irradiation in order to decrease the background arising from reactions on Ce and Pr isotopes. The $^{141}Pr(n,p)$ and $^{141}Pr(n,t)$ reactions lead to the formation of ^{141}Ce and ^{139}Ce having half-lives 32 d and 140 d, respectively. The isotope ^{139}Ce has an isomeric state of 55 sec half-life decaying entirely to the ground state through a 740 keV γ-transition. So, the total reaction cross section could be determined by measuring the 140 d activity. The $^{140}Ce(n,2n)$ and $^{142}Ce(n,2n)$ reactions also yield ^{139}Ce and ^{141}Ce as residual nuclei. One can measure the ^{139}Ce activity only by detecting the 166 keV γ-rays following the electron-capture. However, these γ-rays have to be separated from the 145 keV γ-line, arising from the decay of ^{141}Ce. This was achieved by applying the Ge(Li) spectrometer. The absolute cross section of the reaction $^{141}Pr(n,p)$ was determined through the measurement of the β-activity by a thin mica end-window GM counter. Absolute β-sources were used for calibrating the GM counter.

III. Results and Discussion

The γ-spectra of the irradiated Pr_6O_{11} and CeO_2 samples, are presented in Fig.1. In the case of cerium, both the 145 keV and 166 keV lines did appear, while in the case of praseodymium we obtained the 145 keV line only. The 166 keV line corresponding to the reaction $^{141}Pr(n,t)$ could not be resolved from the background, so for the cross section of this process, we could give an upper limit only. On the basis of the calibration by the ^{169}Yb isotope, the values 144.5 keV and 165 keV were obtained for the energy of the investigated γ -lines.

Table 1 presents the cross section values with the account of errors due to activation and measurement. For determining the (n,t) and $(n,2n)$ cross sections we have accepted the value 11.4 mb obtained by ourselves for the reaction $^{141}Pr(n,p)$. For the purpose of comparison the results of previous measurements are indicated too.

Table 1.

Reaction	σ (mb)		
	present work	literature	calculated
$^{141}Pr(n,p)^{141}Ce$	11.4 ± 1.3	4.5 ± 1 /7/	8.0 /4/ 93.0/ 1/
$^{141}Pr(n,t)^{139}Ce$	< 0.21		
$^{142}Ce(n,2n)^{141}Ce$	1960 ± 170	1600 ± 300(8)	2037/ 5/
$^{140}Ce(n,2n)^{139}Ce$	1600 ± 140		1865 /5/

According to the present measurements, in the case of ^{141}Pr the absolute cross section for the (n,p) reaction can be well described by the empirical relation of Levkovskii /4/. The Gardner-formula /1/ can not be applied to this nucleus.

In the case of the Ce isotopes, a very good agreement has been found between the measured values of $\sigma_{n,2n}$ and those calculated on the basis of the relation given by Pearlstein /5/.

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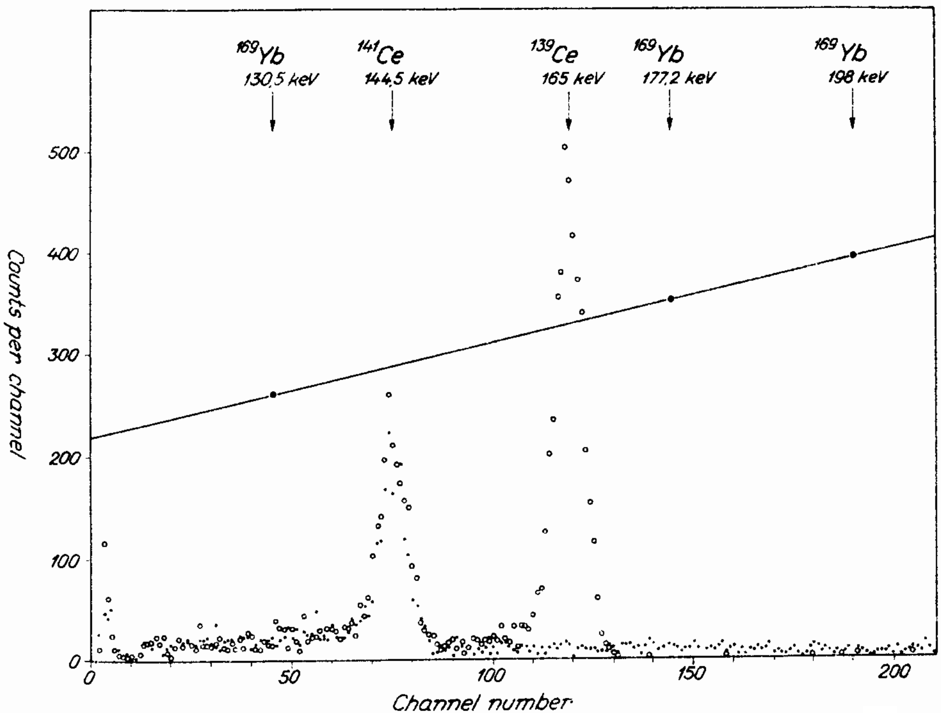

Fig.1. γ - spectrum of cerium (circles) and praseodymium (points) irradiated by fast neutrons.