FLUCTUATION ANALYSIS OF THE $^{29}$Si (d, p) $^{30}$Si REACTION AT 1.1–2.1 MeV

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The excitation functions of the $^{29}$Si(d, p) $^{30}$Si reaction in the deuteron energy range of 1.1–2.1 MeV have been measured in steps of 9.3 keV at angles 40°, 60°, 90°, 100°, 130° and 150° for the following groups of protons: $p_0$ (g.s. of the $^{30}$Si nucleus), $p_1$ (2.23 MeV), $p_2$ (3.51 MeV), $p_{3,4}$ (3.77 and 3.79 MeV), $p_{5,6}$ (4.81 and 4.83 MeV), $p_{10}$ (5.48 MeV) and $p_{11}$ (5.61 MeV). Within the framework of Ericson's theory of statistical fluctuations the autocorrelations, cross-angle correlations and cross-group correlations have been calculated and the mean coherence width $\Gamma$ of the $^{31}$P compound nucleus has been deduced to be 27 keV.

INTRODUCTION

Statistical fluctuations of the nuclear reaction cross sections, predicted theoretically by Ericson [1], were observed in many reactions on light nuclei in a range of energies where a strong overlap of individual resonances occurs. It is possible then by means of statistical fluctuation analysis to determine some characteristics of a compound nucleus, especially the mean coherence width $\Gamma$ or the mean coherence angle $\Delta \Theta$.

In this work attention is given to the study of statistical fluctuations in the (d, p) reaction on the $^{29}$Si nucleus. Existing experimental data about $^{29}$Si (d, p) $^{30}$Si reaction are not complete. Until now the excitation curves in the range of energies of 1–2 MeV for neutron capture on the first six levels have been measured, but without any analysis of the statistical fluctuations [2]. In the work [3] only the fluctuation analysis of the $^{29}$Si (d, $p_0$) $^{30}$Si excitation curve was carried out. We decided to study the fluctuations in the excitation curves of the $^{29}$Si (d, p) $^{30}$Si reaction leading also to the higher states (not only $p_0$) of the final nucleus and to determine the amplitudes $C_\theta(0)$ besides $\Gamma$ and $\Delta \Theta$. The knowledge of the fluctuation amplitudes $C_\theta(0)$ of the excitation curves at different angles can be used for estimation of the direct interaction contributions in the processes leading to the different final states if we are interested in the analysis of angular distributions. Here the results of the fluctuation analysis of measured excitation curves at 40°, 60°, 90°, 100°, 130° and 150° angles for the proton groups $p_0$ (leading to the ground state of the $^{30}$Si nucleus), $p_1$ (2.23 MeV), $p_2$ (3.51 MeV), $p_{3,4}$ (3.77 and 3.79 MeV), $p_{5,6}$ (4.81 and 4.83 MeV), $p_{10}$ (5.48 MeV) and $p_{11}$ (5.61 MeV) are presented. A part of the results of our work has already been published elsewhere [4].

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EXPERIMENTAL PROCEDURE

The measurement of excitation curves was carried out in a target chamber where seven surface barrier silicon detectors (−35 °C cooling temperature, 16−20 keV energy resolution) were mounted. The 4096-channel spectra from all seven detectors were recorded simultaneously on a magnetic tape. Off-line processing was carried out using the HP 2100A computer and a display terminal with a light pen. The targets consisted of a 25 μg/cm² thick layer of SiO₂ with 92% ²⁹Si isotopic enrichment (A.E. R. E. Harwell), evaporated on carbon backing 10 μg/cm² thick. The thickness of the target was checked by the measurement of the intensity of the elastically scattered deuterons compared with the calculated Rutherford cross section. The 0.1−0.2 μA deuteron beam with an energy spread of about 3 keV was produced by the Van de Graaff accelerator in the Nuclear Physics Institute of the Czechoslovak Academy of Sciences. Deuteron energy was changed by steps of 9.3 keV from 1.1 to 2.1 MeV.

In the range of excitation energies of the ³¹P compound nucleus (from 17.8 to 18.8 MeV), corresponding to the energies of incident deuterons, the levels overlap strongly because the level spacing is \( D_0 \sim 0.2 \text{ keV} \) \([5]\), which is much less than the expected value \( \Gamma \sim 30 \text{ keV} \). Also the energy step in the excitation curves is smaller than \( \Gamma \). The target thickness for 1 MeV deuterons is about 9 keV, thus satisfying the condition \( \Delta E < \Gamma \) for observation of Ericson’s fluctuations, where \( \Delta E \sim 10−12 \text{ keV} \) is the overall energy spread including the beam energy resolution and the straggling due to the target thickness. All experimental conditions for observation of fluctuations are then fulfilled.

EXPERIMENTAL RESULTS AND THEIR ANALYSIS

A typical spectrum of protons emitted from the ²⁹Si(d, p) ³⁰Si reaction is shown in Fig. 1. In the spectrum the proton groups \( P_0, P_1, P_2, P_3, P_4, P_5, P_6, P_{10} \) and \( P_{11} \) are well resolved, with negligible influence of a background and also these proton groups are distinguished from those produced in the competing reactions.

![Fig. 1. Typical spectrum for the ²⁹Si(d, p) ³⁰Si reaction at \( E_d = 2.1 \text{ MeV} \) and \( \Theta_{lab} = 90° \) (with the 92% ²⁹Si enriched target).](image-url)