INVESTIGATION OF THE ENERGY SPECTRUM OF DEUTERONS FROM THE REACTION (D,XD) ON THE ^{nat}Cu NUCLEUS AT A DEUTERON ENERGY OF 14.5 MEV

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Introduction

The role of new nuclear physics experiments in building nuclear databases and developing theoretical models in line with current approaches is key in both basic and applied research, related in particular to the development of electronuclear facilities (acceleration system, ADF) for nuclear transmutation of long-lived radioactive nuclear waste and energy production [1]. Work on reactions induced by light charged particles, particularly deuterons, is poorly understood. Reactions in which light complex particles (deuterons, tritons, 3He, and α-particles) are in the input and/or output channels are more difficult to describe, since they have long been recognized to involve other reaction mechanisms, such as direct transfer and nucleon knockout, including cluster degrees of freedom and breakup of an incoming particle [2].

Experimental part

The reaction (d,xd) on the ^{nat}Cu core at E_d= 14.5 MeV was studied on the isochronous accelerator U-150M at INP RK [3]. A self-supporting foil with a thickness of 3.5 microns made of natural copper was used as a target. The thickness and uniformity of the targets used were determined by measuring the energy loss of alpha particles (preparation ^{226}Ra). The reaction products were recorded with an E–E telescope. The double-differential and integral cross sections of the outgoing neutrons were measured in the range of angles 30^0-135^0 in the laboratory mass system. The energy calibration was carried out by peaks corresponding to the known states of the final nuclei (targets ^{12}C and CH_2). The total error of the measured sections did not exceed 10% for all angles.

Teleskop , ΔE-E	ΔE detector thickness , mkm	E detector thicknes s, sm	solid angle, mksr	registered particles	The range of energies in the scm., MeV	Registration angles, $\Delta\theta=15^0$
Si-CsI(Tl)	100	2,5	17,2 ± 0, 3	deuterons	4 ÷ 14,5	30^0÷135^0

Analysis

Experimental data were analyzed within the framework of the phenomenological exciton model of pre-equilibrium decay within the framework of the calculation code PRECO-2006 and TENDL-2019. The developed fast methods for solving kinetic equations have opened up the possibility of studying multiparticle particle emission. The exciton model simultaneously describes the energy spectra of not only nucleons, but also complex particles.

The two-component exciton model assumes that the nucleus is characterized by the parameters p_π, h_π p_ν and h_ν, where p and h denote the partial and hole degrees of freedom, and π-ν denote the proton and neutron degrees of freedom, respectively.

The matrix element form for complex particles has the form:

$$M_{ij}^2 = K_{ij}A^{-3}(20.9 + E/3A_a)^{-3}.$$

In addition to calculations within the exciton model, calculations were carried out within the framework of other mechanisms of nuclear reactions: direct processes (transfer – knocking out of nucleons, inelastic scattering) and equilibrium radiation using the Hauser-Feshbach composite nucleus decay formalism. It is determined that the studied cross-section is mainly formed by mechanisms of pre-equilibrium decay. The contribution of single-stage direct processes is insignificant.

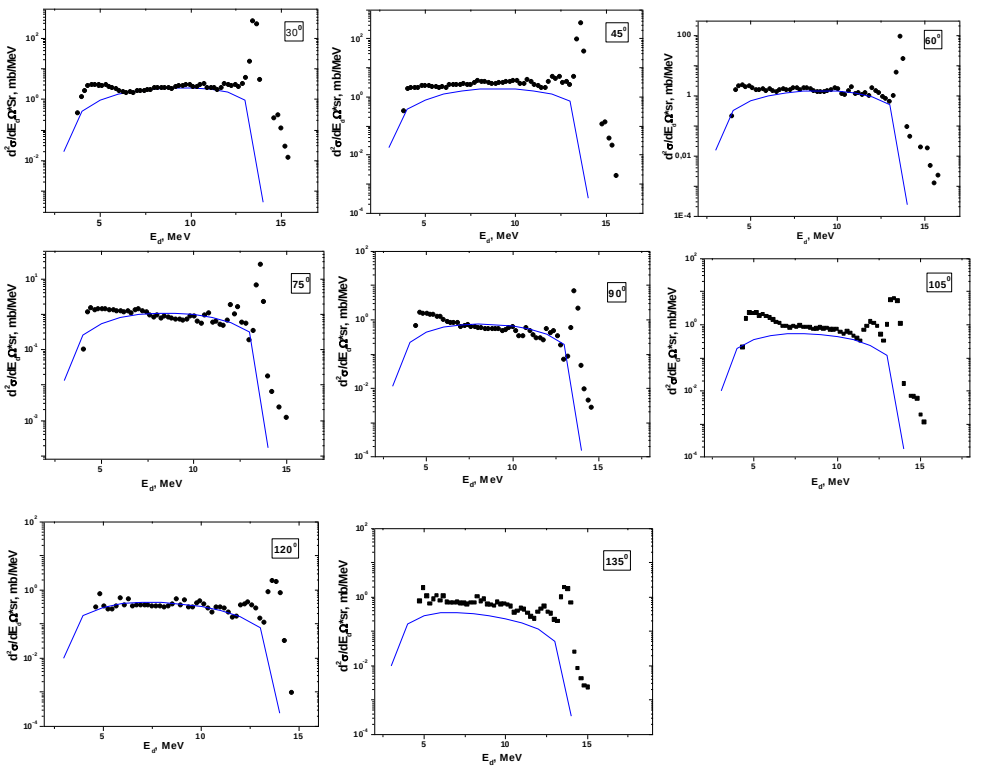

Figure 1. Double-differential cross sections of the reaction (d,xd) at E_d = 14.5 MeV on the ^{nat}Cu at different angles

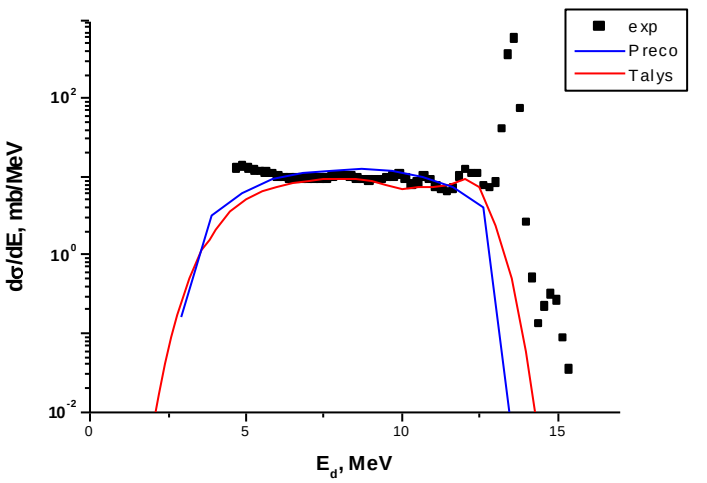

Figure 2 – Comparison of experimental integral cross sections of ^{nat}Cu(d,xd) reactions with calculations within the exciton model. Points - experiment, lines– theoretical calculations

Conclusion

The value of the experimental partial cross-section of the studied reaction was 827.1 ± 2.7 mb. It is established that the main contribution to the formation of the integral cross section of reactions (d,xd) in the energy range up to 12 Mev, corresponding to elastic and inelastic scattering, is provided by the pre-equilibrium mechanism. In the medium-energy part of the spectrum, in addition to the pre-equilibrium, there is a significant contribution of direct processes.

The experimental results obtained fill up the database of nuclear data on reaction cross–sections and can be used in the design of safe and waste-free hybrid nuclear power plants.

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