

## REVIEW

of the Ph.D thesis of Nassurlla Maulen titled **“Effects of cluster structure of stable boron and lithium isotopes to form the outputs of nuclear reaction in the interaction with deuterium and helium isotopes”** submitted in fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) in “6D060500–Nuclear Physics”

The Ph.D thesis of Nassurlla Maulen is devoted to an experimental and theoretical study of the influence of cluster structures of stable lithium and boron isotopes on the formation of yields of nuclear reactions in interactions with deuterons and  $\alpha$ -particles.

### **1. Relevance of the research topic and its relation to the general scientific and national programs**

The nuclei of lithium and boron isotopes have a pronounced cluster structure. In a number of nuclear processes, such a structure can make a dominant contribution to the formation of a cross section in the backward hemisphere. Such a contribution is especially pronounced in the elastic scattering of helium and deuterium ions by lithium isotopes. In this paper, we study the contribution of the cluster exchange mechanism in the nuclear reactions (d, t), ( $\alpha$ , t) on  ${}^7\text{Li}$ ,  ${}^{11}\text{B}$  nuclei. As in the case of elastic and inelastic scattering by light nuclei, analysis of the cross section rise in nuclear reactions can be another direct method for experimentally refining the spectroscopic characteristics of cluster configurations on  ${}^7\text{Li}$ ,  ${}^6\text{Li}$ ,  ${}^{11}\text{B}$  nuclei.

The work was performed as part of scientific research on the topics: “Study of the excited halo states of neutron-rich nuclei  ${}^9\text{Be}$ ,  ${}^{11}\text{B}$ ,  ${}^{13}\text{C}$  in interactions with deuterons” No. GR 0115RK01006 (2015-2017) and “Study of radiation capture and peripheral nuclear transfer reactions of protons at energies near the Coulomb barrier caused by heavy ions for astrophysical and thermonuclear applications, AR05132062/GF (2018-2020).

### **2. The scientific results within a dissertations requirements (pp. 127 "Rules of awarding scientific degrees" 31.03.2011)**

The following research results of the study were obtained in the thesis of Nassurlla Maulen:

– New experimental data were obtained on the differential cross sections for elastic and inelastic scattering of  $\alpha$  particles and deuterons with energies of 7-10 MeV/Nucleon on  ${}^7\text{Li}$ ,  ${}^{11}\text{B}$  nuclei, which substantially supplement the world nuclear data bank.

– The parameters of the optical potential and the strain parameters are determined from a complex analysis of experimental data on elastic and inelastic scattering of deuterons and helium ions on the nuclei of lithium and boron isotopes in the framework of the optical model of the nucleus, by the method of distorted waves and the method of coupled channels;



– In the framework of the coupled channel method, spectroscopic factors for  ${}^7\text{Li}$  and  ${}^{11}\text{B}$  were calculated.

The results obtained in the thesis substantially supplement and refine information on the mechanisms of formation of elastic and inelastic scattering cross sections on  ${}^7\text{Li}$ ,  ${}^{11}\text{B}$  and the characteristics of the studied nuclei.

### **3. The degree of validity and reliability of each scientific result (statement) findings and conclusions set out in applicant's thesis**

The methods of the research that were used during working on this dissertation work are widely known and applied in this field of the research.

The  $\Delta E$ - $E$  method was used for registration and identification of the products of nuclear reactions. The energy spectra of the particles were obtained and processed using the ROOT software package. The theoretical analysis was performed using the FRESCO program code, which includes the theoretical models such as the optical model of the nucleus, the method of distorted wave Born approximation, the double folding model and the method of coupled channels.

19 papers (10 articles, 8 theses and one patent) were published based on the materials of the dissertation, 3 of them were published in the journals recommended by CCES MES RK, 7 articles with non-zero impact factor (European Physical Journal - Impact factor 2.799) were published in the journals indexed by Thomson Reuters and Scopus. The sufficiency of the completeness of publications of scientific results is beyond doubt.

### **4. The degree of novelty of each scientific result (statement), applicant's conclusion set out in the thesis**

In the course of the thesis, doctoral candidate Nassurlla M. obtained the following new results:

1. Differential cross sections of nuclear reactions  ${}^7\text{Li}(d,d){}^7\text{Li}$  and  ${}^7\text{Li}(d,t){}^6\text{Li}$  at energies of 14.5 and 25 MeV,  ${}^{11}\text{B}(d,t){}^{10}\text{B}$  at an energy of 14.5 MeV and  ${}^{11}\text{B}(\alpha,t){}^{12}\text{C}$  at an energy of 40.0 MeV and their analysis according to the optical model of the nucleus and the method of distorted waves, eliminates the discrete ambiguity of the real part of the potential for the systems " $d+{}^7\text{Li}$ ", " $d+{}^{11}\text{B}$ " and " $\alpha+{}^{11}\text{B}$ " in a wide energy range.

2. The established values of the quadrupole deformation parameters of the  ${}^7\text{Li}$  nuclei ( $\beta_2=1.1\pm 0.3$ ) and  ${}^{11}\text{B}$  ( $\beta_2=-0.80\pm 0.2$ ), taking into account the channel coupling between the ground and excited states of the studied nuclei, reduce the deviations of the calculated cross sections from experimental ones in the range of average angles to 20–30%.

3. The established values of the spectroscopic factors of the cluster configurations  ${}^7\text{Li}\rightarrow"d+t"$  ( $SF=1.19$ ) and  ${}^{11}\text{B}\rightarrow"2\alpha+t"$  ( $SF=1.0$ ) correctly reproduce the rise of the reaction cross sections ( $d, t$ ) and ( $\alpha, t$ ) under reverse angles on the studied nuclei and justify their cluster structures.



## 5. Practical and theoretical significance of the results

The scientific results obtained by the dissertation have the following practical and theoretical significance:

- The obtained experimental cross sections at energies of 7-10 MeV/nucleon can significantly supplement the world nuclear data bank, the IAEA library.
- Optical potentials, deformation parameters, and spectrofactors for the studied nuclei established from a complex analysis of differential cross sections for elastic and inelastic scattering within the framework of the phenomenological approach can be used in model calculations for astrophysical and thermonuclear applications.

## 6. Comments, suggestions for thesis

An experimental proof of the presence of the cluster configuration in the  $^{11}\text{B}$  nucleus " $2\alpha+t$ " would be an analysis of the angular distributions of alpha-particle scattering for the 8.56 MeV ( $3/2^-$ ) excited state of the nucleus under study.

The same can be said for the case of scattering of deuterons by  $^{11}\text{B}$  nucleus at energy of 14.5 MeV. It is unclear whether there are angular distributions for this level for such analysis within the framework of this work.

In contrast to the reaction  $^{11}\text{B}(\alpha, t)^{12}\text{C}$ , the experimental data for the reaction ( $d, t$ ) are measured only up to  $140^\circ$  degrees in the center of mass system.

The noted shortcomings do not reduce the value of the results obtained by the author and can not affect to the overall positive evaluation of the work.

## 7. Compliance of the thesis content within the requirements of "Rules of awarding of scientific degrees"

The considered thesis is executed on a high professional level with use of complex methods of modern nuclear physics. It is written in clear language, using the accepted terminology.

In my opinion, the current thesis "**Effects of cluster structure of stable boron and lithium isotopes to form the outputs of nuclear reaction in the interaction with deuterium and helium isotopes**" fully meets the requirements of the Committee for Control of Education and Science of the MES RK, and its author, Nassurlla Maulen, is worthy of awarding her a degree of Doctor of Philosophy (Ph.D) in the specialty "6D060500 - Nuclear Physics".

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