REVIEW

on the PhD dissertation of Alessya Tkachenko entitled «Phase shift analysis of nuclear processes with the spin structure 1+1/2, 1+1, 1/2+3/2 and astrophysical applications» and submitted for the degree of Doctor of Philosophy (PhD) in the specialty «6D060500 – Nuclear Physics».

1 Relevance of the research topic and its relationship with general scientific and national programs

The PhD research by Alessya Tkachenko provides the mathematical formalism for the phase shift analysis of nuclear processes with the high value of the channel spin $S>1/2$ (for both, integer and half-integer channel spin values). A detailed phase shift analysis further opens up the possibility of constructing binary interaction potentials of varying complexity, based on which one can calculate the characteristics of nuclear reactions.

Besides, the dissertation contains examples of modified potential cluster model (MPCM) application, that allows one to reconstruct the interaction potentials in a fixed binary cluster channel relying on the experimental data of elastic scattering, such as the observed energy spectra and ACs for the bound states, as well as measured geometric characteristics such as charge and mass radii. In terms of MPCM the reactions $^{3}\mathrm{He}(^{2}\mathrm{H},\gamma)^{5}\mathrm{Li}$ and $^{10}\mathrm{Be}(n,\gamma)^{11}\mathrm{Be}$ are considered, and reactions characteristics obtained can make an essential contribution to the concept of synthesis of light elements during the BBN.

The research topic corresponds to the programs of the Ministry of Education and Science of the Republic of Kazakhstan in the field of fundamental research.

2 Scientific results and the level of their validity

The following reliable scientific results are formulated in the PhD dissertation:

1. The total differential cross sections can be presented using the analytical expressions, parametrized with respect to the arbitrary orbital angular momentum ℓ and take into account spin-orbit interaction. It is possible for processes with integer and half-integer channel spin value and allows one to extract the scattering phase shifts.

2. In the framework of MPCM based on experimental data the *S*-factor or total cross section of the radiative $^{3}\mathrm{He}(^{2}\mathrm{H},\gamma)^{5}\mathrm{Li}$ capture reaction and the reaction rate obtained. Moreover, the possible contribution of the neutron capture on $^{5}\mathrm{Li}$ to the formation of a stable $^{6}\mathrm{Li}$ is considered qualitatively.

3. Neutron radiative capture process on $^{10}\mathrm{Be}$ at the energy 25.3 meV – 10.0 MeV is considered in order to demonstrate the capabilities of the MPCM in the context of phase shift analysis. $^{10}\mathrm{Be}(n,\gamma)^{11}\mathrm{Be}$ reaction rate and total cross section is calculated in agreement with available experimental data.

3 The degree of validity and reliability of each scientific result (scientific provision) and conclusions, formulated in the dissertation is ensured by the presence of publications in peer-reviewed international scientific journals *Nuclear*

Physics A (2 articles, IF= 1.463) and *Astroparticle Physics* (1 article, IF= 3.203), as well as in local and Russian scientific journals recommended by the Committee for Control of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan or equivalent to them. Alessya Tkachenko has 14 scientific publications in total, including international conferences proceedings.

4 The degree of novelty of each scientific result (provision), the conclusion of the applicant, formulated in the dissertation

1. A universal mathematical formalism developed in the dissertation research has no analogues in scientific literature. It allows one to perform the phase shift analysis taking into account spin-orbit and spin-spin interactions.

2. Using the modified potential cluster model allows to reproduce the experimental total cross sections of the ^{3}He(^{2}H,γ)^{5}Li process at energies up to 5 MeV. The role of the ^{3}He(^{2}H,γ)^{5}Li process for the formation of ^{6}Li in the Big Bang nucleosynthesis is suggested. This process participates in a two-step mechanism $^2\mathrm{H} + {}^3\mathrm{He} \rightarrow {}^5\mathrm{Li} + \gamma$; $n + {}^5\mathrm{Li} + \gamma \rightarrow {}^6\mathrm{Li} + \gamma$.

3. In the framework of MPCM the interaction potentials of n^{10}Be were constructed. Based on these potentials the analytical scattering phase shifts were obtained. These potentials also reproduce correctly the general trend of experimental data for the total cross-sections of the neutron radiative capture on ^{10}Be nucleus at low and ultralow energies.

5 Practical and theoretical significance of scientific results

The results presented by the applicant have both theoretical value and practical applicability.

The application area of the obtained mathematical formalism is not limited only to astrophysical problems; it can be used, for example, in the study of low-energy processes in plasma physics, in particular, to take into account quantum-mechanical effects, as well as in problems of hadron and meson scattering in intermediate-energy physics.

In the future, based on the presented analytics, it is possible to create program codes and software for the consistent phase shift analysis based on the modern experimental data.

The obtained characteristics of $^3\mathrm{He}(^2\mathrm{H},\gamma)^5\mathrm{Li}$ and $^{10}\mathrm{Be}(n,\gamma)^{11}\mathrm{Be}$ processes contributes noticeably to the understanding of BBN.

Particular attention should be paid to the scattering phase shifts of the radiative neutron capture reaction $^{10}\mathrm{Be}(n,\gamma)^{11}\mathrm{Be}$ obtained on the base of interaction potentials constructed in the framework of MPCM. Application of this model was so successful that the phase shifts obtained may be considered as a starting point for future consistent phase shift analysis, further reconstruction and refinement of interaction potentials or programs debugging.

6 Comments, suggestions for the dissertation

1 The computer program given in Appendix 2 is quite voluminous, so extended comments could be written to the text of the program. This would make the program easier to understand. Applicant can also clarify the reason why some parts of the program are commented out.

2 It is possible to give the mixing parameters for inelastic channels, at least for the most significant reactions. This allows a comprehensive assessment of the complexity of the problem being solved in each individual case.

3 In Formula (3.7) for $N_A\langle\sigma v\rangle$, the numerical values of the parameters are given. It would be more consistent to give a general expression for the reaction rate first, for example from the paper of C. Angulo (Ref. [127]).

4 The dissertation contains minor number of stylistic inaccuracies and typographical errors.

7 Compliance of the content of the dissertation within the requirements of the "Rules for the award of academic degrees"

Despite the comments and remarks given above, the results and conclusions of the research are scientifically significant. The dissertation of Alessya Tkachenko **"Phase shift analysis of nuclear processes with the spin structure 1+1/2, 1+1, 1/2+3/2 and astrophysical applications"** is a completed scientific and qualification work. PhD dissertation on the relevance, scientific novelty, practical and theoretical significance of the results meets the requirements of the Committee for Control of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan. I suppose that Alessya Tkachenko deserves to be awarded the degree of Doctor of Philosophy (PhD).

Подпись указанного лица удостоверяю
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