REVIEW

of the official reviewer for dissertation work
of Yeleusheva Badigul Maratovna on the topic «Radiative capture reactions on light nuclei in stellar and interstellar plasma», presented for the degree of Doctor of Philosophy (PhD) of the educational program «8D05308 - Nuclear physics»

№	Criteria	Eligibility (one of the options must be checked)	Justification of the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs	1.1 Compliance with priority areas of science development or government programs: **1) The thesis was completed within the framework of a project or target program financed from the state budget (indicate the name and number of the project or program)** 2) The thesis was completed within the framework of another state program (indicate the name of the program) **3) The dissertation corresponds to the priority direction of the development of science, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction)**	The thesis was completed within the framework of projects financed from the state budget: "Study of the rates of some thermonuclear reactions in solar cycles and BBN" (IRN: AP09259021-OT-23, 2021-2023); "Study of the processes of thermonuclear hydrogen combustion in the CNO cycle on the Sun and in stars" (IRN: AP19676483, 2023-2025) – and corresponds to the priority direction of the development of science "Scientific research in the field of natural sciences", approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan
2.	Importance for science	The work **makes**/does not make a significant contribution to science, and its importance is well disclosed/not disclosed	The work makes a significant contribution to nuclear astrophysics in part of stellar and inter-stellar nucleosynthesis of unstable neutron-rich isotopes ^{9}Li, ^{10}Be, ^{14}B. The cross sections of the corresponding fusion reactions and the rates of formation of those isotopes were calculated in the framework of modified potential cluster model. Also the production of ^{16}O by p-processes was revised in this

			framework. All this can improve the light elements evolution scenarios. The importance of the work is well disclosed in the corresponding chapters and the Conclusion.
3.	The principle of independence	Self-reliance level: **1) High;** 2) Medium; 3) Low; 4) No independence	The self-reliance level is high, since all the parts of the work, including review of the problem, analytical and numerical calculations, analysis of the obtained results, represent an independent research.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: **1) Justified;** 2) Partially justified; 3) Not justified.	The relevance of the thesis was totally justified in the Introduction, as there is a way for solving the most actual astrophysical problems: the early Universe's formation and evolution theory; models for the synthesis of chemical elements; accumulation of heavy isotopes; solar and stellar Carbon-Nitrogen-Oxygen cycles.
		4.2 The content of the thesis reflects the topic of the thesis: **1) Reflects;** 2) Partially reflects; 3) Does not reflect	The topic of the thesis was reflected in all parts of the work: radiative capture reactions $^{8}Li(n,\gamma)^{9}Li$, $^{9}Be(n,\gamma_{0+1+2+3+4+5})^{10}Be$, $^{13}B(n,\gamma_{0+1})^{14}B$, and $^{15}N(p,\gamma)^{16}O$ were considered in Sections 2, 3, 4 and 5, respectively; Section 1 presents the model approach and elements of formalism for the radiative capture processes; the relevance to study such capture processes was justified in the Introduction part; and the conclusion on the results of this study was made in the last part of the work.
		4.3. The purpose and objectives correspond to the topic of the thesis: **1) correspond;**	The clear and precise formulation of the purpose and objectives in the Introduction leaves no doubts that they totally correspond

		2) partially correspond; 3) do not correspond	to the topic of the thesis, as all of them are aimed to study the same type of fusion reactions
		4.4 All sections and provisions of the thesis are logically interconnected: **1) completely interconnected;** 2) the interconnection is partial; 3) there is no interconnection	All sections and provisions of the thesis have very close logical interconnection, as all of them develop and use one the same theoretical method for one type of fusion reactions
		4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions: **1) there is a critical analysis;** 2) partial analysis; 3) the analysis does not represent one's own opinions, but quotes from other authors; 4) no analysis	The new solutions proposed by the author and listed in the Introduction are reasoned and evaluated in comparison with the known solutions in detailed review confirmed by references
5.	Scientific novelty principle	5.1 Are the scientific results and provisions new? **1) completely new;** 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The scientific results and provisions submitted for defense are completely new. Total cross sections for radiative n^8Li capture at different energies were obtained, generally agreeing with experimental measurements. Partial and total cross-sections for the $^9Be(n,\gamma)^{10}Be$ reaction were calculated from 10^{-5} to 5 MeV. The expanded energy range allows for considering five resonances, with the resonance at E_x = 0.730 MeV identified. The impact of asymptotic constants on cross-sections and reaction rates was demonstrated. Total cross sections for the $^{13}B(n,\gamma)^{14}B$ reaction were calculated for the first time from 10^{-2} eV to 5 MeV, with thermal cross-sections in the range of 5.1–8.9 mb. Reaction

			rates were calculated over a temperature range of 0.01 to 10^9 K, with ignition T_9 values determined based on neutron number density.
		5.2 Are the dissertation findings new?	The findings of the dissertation are completely new. For the first time: 1. A model-free criterion for evaluating the reliability of the calculated reaction rates is proposed due to the binding energy in the nucleon channels $^{6}Li(n,\gamma)^{7}Li$, $^{7}Li(n,\gamma)^{8}Li$, and $^{8}Li(n,\gamma)^{9}Li$. 2. The partial and total cross-sections of the $^{9}Be(n,\gamma)^{10}Be$ reaction calculated in the energy range from 10 eV to 5 MeV allow to consider five resonances and estimate their signature in the total cross-section. 3. The calculations of the total cross sections of $^{13}B(n,\gamma_{0+1})^{14}B$ reaction performed in MPCM from 10^{-2} eV to 5 MeV provide the proposal for new experimental measurements ISOLDE. 4. The $^{15}N(p,\gamma)^{16}O$ reaction rate has negligible dependence on the variation of asymptotic constant, but shows a strong impact of the interference. 5. The regularity "the higher the channel threshold, the higher the reaction rate" is new and the same is formulated for neighbouring isotopes Li, B and, N.
		1) completely new;	
		2) partially new (25-75% are new);	
		3) not new (less than 25% are new)	
		5.3 Technical, technological, economic or management decisions are new and reasonable:	The scientific decisions obtained in the Thesis are completely new and reasonable, but they are not technical, technological, economic or management ones.
		1) completely new;	
		2) partially new (25-75% are new);	
		3) not new (less than 25% are new)	

6.	The validity of the main findings	All main conclusions **are**/are not based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities)	All main conclusions are based on scientifically significant evidence and well-grounded, but the research is also a quantative research and its main basis and grounds are physical laws and mathematical calculation. The theoretical research conducted by the dissertation has led to findings that demonstrate scientific validity, since the main conclusions are confirmed and proven, as the author relies on previously analyzed scientific documentation and factual data confirmed by methods and theories.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? **1) proven;** 2) rather proven; 3) rather not proven; 4) not proven; 5) in the current formulation, it is impossible to verify the proof of the position 7.2 Is it trivial? 1) yes; **2) no;** 3) in the current formulation, it is impossible to verify the triviality of the position 7.3 Is it new? **1) yes;** 2) no; 3) in the current formulation it is impossible to verify the novelty of the provision	**Provision #1** - Two criteria found for the evaluation of $^{8}Li(n,\gamma_{0+1})^{9}Li$ reaction rate allow to *narrow down* the range of reaction rates and *constrain* the choice of asymptotic constants. **Provision #2** – The partial and total cross-sections of $^{9}Be(n,\gamma_{0+1+2+3+4+5})^{10}Be$ reaction calculated in the energy range from 10^{-5} to 5 MeV *allows to consider* five resonances and *estimate* their contribution to the total cross-section. **Provision #3** - The calculations of the total cross sections of $^{13}B(n,\gamma_{0+1})^{14}B$ reaction and the presented data on the reaction rates substantiate that $^{13}B(n,\gamma_{0+1})^{14}B$ reaction is not the *break-point* of the Boron sequence in the Boron-Carbon-Nitrogen chains. 7.1 All provisions are proven in the dissertation work 7.2 All provisions are not trivial 7.3 All provisions are completely new

		7.4 Application level: 1) narrow; **2) medium;** 3) wide; 4) in the current formulation, it is not possible to verify the level of application of the provision 7.5 Is it proven in the article? **1) yes;** 2) no; 3) in the current formulation, it is impossible to verify the evidence of the position in the article	7.4 The application level of all provisions are medium 7.5 All provisions are proven in articles
8.	The principle of reliability. Reliability of sources and information provided	8.1 Choice of methodology - is justified or the methodology is described in sufficient detail **1) yes;** 2) no	The modified potential cluster model used in the dissertation are described in detail in the dissertation work with all the features of the mathematical apparatus used in the calculations. The choice of methodology is justified and supported by references to the proven scientific sources and the results obtained in the dissertation.
		8.2 The results of the thesis were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies: **1) yes;** 2) no	The results of the thesis were obtained using the modified potential cluster model was used. This approach is a modern method of scientific research using computer technologies.
		8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment): **1) yes;** 2) no	All results of the dissertation research were compared with the available experimental data and showed good agreement with them.

		8.4 Important statements are **confirmed**/partially confirmed / not confirmed by references to current and reliable scientific literature	The important statements in the text of the dissertation research are confirmed by references to reliable scientific literature in the References section of the Thesis.
		8.5 Used literature sources are **sufficient**/not sufficient for a literature review	196 literature sources were used for the literature review on the problem of the Thesis and referenced in the References section, and this is more than sufficient for that.
9	Practical value principle	9.1 The thesis has theoretical value: **1) yes;** 2) no	The dissertation has high theoretical value, as it offers both new approaches and new knowledge in the theoretical study of the processes of interaction in light nuclei: $n^{8}Li$, $n^{9}Be$, $n^{13}B$, $p^{15}N$
		9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: **1) yes;** 2) no	The thesis has the practical importance and there is a high probability of applying the results obtained in practice, since the results of calculations of the reaction cross sections $^{8}Li(n,\gamma_{0+1})^{9}Li$ and $^{13}B(n,\gamma_{0+1})^{14}B$ within the framework of the Thesis actually provide a justification for setting up new experimental measurements both at thermal energies and in an extended range up to 5 MeV.
		9.3 Are the practice suggestions new? **1) completely new;** 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The practice suggestion to set up a new experimental measurements both at thermal energies and in an extended range up to 5 MeV is completely new, as such energies are new for ISOLDE project.
10.	The quality of writing and design	Academic writing quality: **1) high;** 2) average; 3) below average; 4) low.	The dissertation is distinguished by the high quality of academic writing, which is manifested in the clarity and accuracy of presentation, logical structure, argumentation and evidence, as well as compliance with scientific style and language.

11.	Notes on the thesis	1) The Thesis possibly needs an individual section to preliminary review/discuss the general problem under the research. 2) The list of research methods in Introduction of the Thesis is too general.
12.	Scientific level of the doctoral student's articles on the topic of research (in case of defense of the dissertation in the form of a series of articles, the official reviewers comment on the scientific level of each article of the doctoral student on the topic of research)	Scientific level of the doctoral student's articles on the topic of research is very high. The applicant has published 4 articles on the topic of the dissertation research, including the following publications in scientific journals indexed in the Scopus\Web of Science database: 1) The reaction rate of radiative n^8Li capture in the range from 0.01 to 10T_9 // Frontiers in Astronomy and Space Sciences. – 2023. – Vol. 10. – 1251743. 2) Estimation of radiative capture $^{13}B(n,\gamma_{0+1})^{14}B$ reaction rate in the modified potential cluster model // Chinese Physics C. – 2023. – Vol. 47. – 104103. 3) Radiative $^{9}Be(n,\gamma_{0+1+2+3+4+5})^{10}Be$ reaction rate in the potential cluster model // Chinese Physics C. – 2023. – Vol. 47. – 084105. 4) Astrophysical S-factor and reaction rate for $^{15}N(p,\gamma)^{16}O$ within the modified potential cluster model // Chinese Physics C. – 2024. – Vol. 48. – 044104.
13.	Decision of the official reviewer	The work of Yeleusheva Badigul Maratovna on the topic " Radiative capture reactions on light nuclei in stellar and interstellar plasma " submitted for the degree of Doctor of Philosophy (PhD) in the educational program "8D05308 - Nuclear Physics" meets all the requirements and is deserving of being awarded the academic degree of Doctor of Philosophy (PhD).

Official Reviewer:
L.N.Gumilyov Eurasian National University
PhD

Temerbayev Azamat Aliyevich