REVIEW
of the official reviewer for dissertation work
ARSHYN ZHENGIS on the theme «*Preparation of a Novel Multifunctional Zwitterionic Polymeric Membrane*» presented for the degree of Doctor of Philosophy (PhD) in the specialty «*8D05301-Chemistry*».

№	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 carried out within the framework of a scientific project of the Ministry of Science and Higher Education of the Republic of Kazakhstan, "Theoretical and Experimental Studies of Amphiphilic Polybetaine Self-Assembly and Function" grant number AP13067633 2022-2024
2.	Importance for science	The work makes/does not make a significant contribution to science, and its importance is well disclosed/not disclosed	The dissertation is devoted to the development and investigation of zwitterionic polymeric materials and their application in membrane-based water purification technologies. The topic is scientifically relevant, as the design of advanced antifouling membranes and selective separation materials is a critical challenge in modern environmental and materials science. The author investigates the synthesis, physicochemical properties, and self-assembly behavior of sulfobetaine-based zwitterionic polymers, as well as their integration into hybrid membrane systems. Particular attention is

			given to understanding the structure–property relationships of these polymers and their influence on membrane performance, including permeability, selectivity, and antifouling behavior. The obtained results contribute to the development of new approaches for designing high-performance membrane materials. The combination of zwitterionic polymers with metal–organic frameworks (ZIF-8) to create hybrid membranes represents a promising direction for improving water treatment technologies and addressing global challenges related to clean water production and wastewater purification. Therefore, the work makes a meaningful contribution to the field of functional polymeric materials and membrane science, and its scientific importance is clearly demonstrated.
3.	The principle of independence	Self-reliance level: **1) High;** 2) Medium; 3) Low; 4) No independence	The doctoral student shows a high level of independence in this research. The author studied the related scientific literature well and carried out the experimental work on synthesis, characterization, membrane preparation, and performance testing. The results were analyzed carefully and presented in a clear way. The work shows that the student is able to plan research, carry out experiments, and make scientific conclusions independently.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: **1) Justified;** 2) Partially justified; 3) Not justified.	The topic of the dissertation is relevant and important. It focuses on advanced membrane materials for water purification, which is a current issue in science and technology. The study is important because clean water and better treatment methods are needed worldwide.

		4.2 The content of the thesis reflects the topic of the thesis: **1) Reflects;** 2) Partially reflects; 3) Does not reflect	The content of the dissertation reflects the title and topic of the thesis well. All papers are related to the preparation, study, and application of zwitterionic polymeric membranes and related materials.
		4.3. The purpose and objectives correspond to the topic of the thesis: **1) correspond;** 2) partially correspond; 3) do not correspond	The aim and objectives of the dissertation match the topic of the study. The tasks are clearly stated and are suitable for achieving the research goal.
		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 parts of the dissertation are connected in a logical way. The literature review, methods, results, and discussion support each other well and lead clearly to the final conclusions.
		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	The author compares the developed materials and methods with published studies from other researchers. The dissertation includes analysis of existing membrane materials and explains the advantages of the proposed approach.
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 of the dissertation are partially new. Zwitterionic polymers and membrane materials have been studied before by other researchers. However, the author developed new membrane systems and studied their properties, structure, and performance for water purification. The work provides additional understanding of how these materials behave and how their properties can improve membrane performance. Therefore, the study contributes new experimental data and analysis to the existing research area.

		5.2 Are the dissertation findings new? 1) completely new; **2) partially new (25-75% are new);** 3) not new (less than 25% are new)	The findings of the dissertation extend existing knowledge in polymer membrane science. While the general concept of zwitterionic membranes is known, the author provides new experimental results on synthesis, membrane fabrication, and performance evaluation. These results help to improve understanding of the relationship between polymer structure and membrane function.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) completely new; **2) partially new (25-75% are new);** 3) not new (less than 25% are new)	The technological approaches used in the study are based on known membrane preparation methods. However, the author introduces modified materials and combines different components to improve membrane properties. These improvements represent useful development of existing technologies rather than completely new technologies.
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)	The main conclusions of the dissertation are based on experimental results and scientific evidence. The author used suitable methods for synthesis, characterization, and membrane testing. The conclusions are supported by the data presented in the dissertation and agree with the discussion of the results.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provition proven? **1) proven;** 2) rather proven; 3) rather not proven; 4) not proven 7.2 Is it trivial? **1) yes;** 2) no	The main provisions presented for defense are supported by the results of the research. The developed materials, methods, and membrane performance were studied experimentally and explained clearly. The results are also supported by the published articles included in the dissertation. The presented provisions are not trivial and have scientific and practical value.

		7.3 Is it new? **1) yes;** 2) no 7.4 Application level: 1) narrow; 2) medium; **3) wide** 7.5 Is it proven in the article? **1) yes;** 2) no	
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 research methods are suitable for the aim of the study and are described clearly enough.
		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 were obtained using modern experimental and analytical methods commonly used in polymer and materials research.
		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	The theoretical explanations and conclusions are supported by the experimental results presented in the dissertation.

		8.4 Important statements are confirmed / partially confirmed / not confirmed by references to current and reliable scientific literature	**Confirmed** Important statements in the dissertation are supported by relevant and up-to-date scientific references.
		8.5 Used literature sources are sufficient/not sufficient for a literature review	**Sufficient** The dissertation uses enough scientific literature for the review. The cited references are relevant to the topic and help support the discussion.
9	Practical value principle	9.1 The thesis has theoretical value: **1) yes;** 2) no	The dissertation has theoretical value because it improves understanding of zwitterionic polymers and their behavior in membrane systems.
		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 dissertation has practical importance because the developed materials and results can be useful for water purification and membrane separation applications.
		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 practical suggestions are useful and partly new. They may support future work on better membrane materials with improved performance.
10.	The quality of writing and design	Academic writing quality: **1) high;** 2) average; 3) below average; 4) low.	The dissertation is presented in the form of a series of published research articles. The material is organized clearly and logically, and the structure of the dissertation is appropriate for this format. The academic writing is of good quality, and the published articles adequately reflect the objectives and results of the dissertation research.
11.	Notes on a thesis	Overall, the dissertation presents meaningful results in the field of functional polymeric materials and membrane technology. The work is well structured and supported by published research articles. However, several points could be improved. First, a deeper discussion comparing the developed membrane	

		materials with previously reported systems would further highlight the advantages and limitations of the proposed approach. Second, additional explanation on the long-term stability and practical application of the membranes could strengthen the practical significance of the study. Furthermore, some sections could benefit from more detailed discussion on the relationship between polymer structure and membrane performance to better explain the observed results. These comments are mainly recommendations for further improvement and do not reduce the overall scientific value of the dissertation.
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)	The results of the dissertation research are presented in several scientific articles published in international peer-reviewed journals. The first article, published in *Polymer*, is a review paper that summarizes current knowledge on SBMA-based zwitterionic membranes, including synthesis methods, antifouling mechanisms, and future research directions. The article provides a useful overview of the field and demonstrates the author's understanding of the scientific background of the research. The second article, published in *Nanomaterials*, focuses on the synthesis and characterization of sulfobetaine-based zwitterionic polymers and their thermal and self-assembly properties. The work presents experimental results that contribute to understanding the relationship between polymer structure and material properties. The third article, published in *ACS Applied Materials & Interfaces*, reports the development of a zwitterionic polymer–MOF hybrid membrane for water filtration. The study demonstrates improved membrane performance and provides valuable results for the development of advanced membrane materials for water purification applications. Overall, the published articles reflect the main objectives and results of the dissertation research and demonstrate the scientific contribution of the doctoral student to the field of functional polymeric materials and membrane technology.
13.	Decision of the official reviewer (pursuant to paragraph 28 of the present Model Regulations)	The dissertation work of **Arshyn Zhengis** entitled **"Preparation of a Novel Multifunctional Zwitterionic Polymeric Membrane"** presents research results that contribute to the development of functional polymeric materials and membrane technologies for water purification. The research objectives have been achieved, the obtained results are supported by experimental data, and the main findings have been published in reputable scientific journals. The dissertation meets the

		requirements for doctoral dissertations. Based on the above, the dissertation deserves a positive evaluation, and **it is recommended to award the degree of Doctor of Philosophy (PhD) in the educational program "8D05301 – Chemistry".**

In reviews, official reviewers indicate one of the following solutions:

1) to award the degree of Doctor of Philosophy (PhD);

2) send the thesis for revision (except for cases of thesis defense in the form of a series of articles);

3) refuse to award the degree of Doctor of Philosophy (PhD).

Copies of the reviews of the official reviewers are handed over to the doctoral student no later than 5 (five) working days before the defense of the thesis.

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(place of work, academic title) (signature) (FULL NAME)