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 speciality «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) <u>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)</u> 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 financed by grants: 1) Advancement of the Green Energy: Foundational Research of Solar Fuel Technologies for Sustainable Production and Advanced Storage (Grant No. BR21882439). 2) Theoretical and experimental studies of amphiphilic polybetaine's self-assembly and function (Grant No. AP13067633);
2.	Importance for science	The work **<u>makes</u>**/does not make a significant contribution to science, and its importance is well disclosed/not disclosed	The work represents a significant contribution to both science and society. This study advances the understanding of zwitterionic polymers, particularly their thermal behavior and structure–property relationships, as well as their application in membrane-based technologies. The synthesis and fabrication methods are clearly

			described, and the underlying application mechanisms are thoroughly investigated. Overall, the research provides a valuable and meaningful contribution to the advancement of scientific knowledge in this field.
3.	The principle of independence	Self-reliance level: 1) **High;** 2) Medium; 3) Low; 4) No independence	The PhD candidate demonstrates a high degree of scientific independence. She is the first author on three of the four articles, underscoring her leading role in the research. Overall, she shows considerable promise and establishes a strong foundation as an emerging young scientist.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: 1) **Justified;** 2) Partially justified; 3) Not justified.	The thesis addresses a highly relevant research area and exhibits clear scientific originality, contributing novel insights to the field.
		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 thesis is well aligned with its stated topic, demonstrating clear coherence and focus throughout.
		4.3. The purpose and objectives correspond to the topic of the thesis: 1) **correspond;** 2) partially correspond; 3) do not correspond	The aims and objectives are clearly defined and appropriately aligned with the stated topic, reflecting a coherent and well-structured research framework.
		4.4 All sections and provisions of the thesis are logically interconnected: 1) **completely interconnected;**	The thesis is coherent and internally consistent, with its components effectively integrated into a unified

		2) the interconnection is partial; 3) there is no interconnection	work.
		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 developed synthesis and material fabrication procedures are rigorously benchmarked against existing methods, with comprehensive evaluation in terms of applicability, characterization, and performance.
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)	Yes, the scientific results and provisions are novel and demonstrate a high degree of originality. Zwitterionic monomers were synthesized via nucleophilic ring-opening of 1,3-propanesultone and polymerized into four distinct polymers (pSBMAm, pSB2VP, pSB3VP, and pSB4VP). Despite identical functionalization, the polymers exhibited significantly different molecular weights, highlighting the key role of backbone structure in polymerization behavior. The polymers also showed distinct thermal and self-assembly properties, with increasing glass transition temperatures indicating reduced chain mobility, and pH-dependent TEM revealing variations in nanostructure formation. In application, the SBMA–ZIF-8 hybrid membrane demonstrated high water flux, excellent rejection of heavy

			metals and dye, and stable performance over repeated cycles. Overall, the work provides a meaningful and original contribution to the understanding and application of zwitterionic polymers in membrane-based separation technologies.
		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)	Yes, the dissertation findings are novel. The study introduces original approaches to the synthesis and design of zwitterionic polymers, reveals new insights into their structure–property relationships and self-assembly behavior, and demonstrates their effective application in advanced membrane technologies.
		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 technical and technological decisions proposed in the thesis are novel and well grounded. They are supported by thorough experimental and computational analysis, ensuring their scientific validity and practical applicability in membrane-based separation processes.
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 procedures were systematically developed and rigorously validated in accordance with established standards and best practices in the field.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately:	The provision 1 is proven in the article

		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** 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	https://doi.org/10.3390/nano15010058 : four types of monomers were first synthesized, subsequently polymerized, thoroughly characterized, and their molecular weights reliably determined. The provision is new and is not trivial.
	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** 7.3 Is it new? 1) **yes;** 2) no 7.4 Application level: 1) narrow;	The provision 2 is proven in the article https://doi.org/10.3390/nano15010058 The thermal properties of the materials, including their glass transition temperatures, as well as the pH-dependent self-assembly behavior of the polymers, have been systematically investigated. These findings substantiate the novelty of the provision.

		2) **medium;** 3) wide 7.5 Is it proven in the article? 1) **yes;** 2) no	
	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** 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	The provision 3 is proven in the article: https://doi.org/10.1021/acsami.5c16282 The Zwitterion-MOF hybrid membrane was fabricated using NIPS and in situ methods, with both the fabrication process and performance thoroughly described. The underlying mechanisms are clearly explained and strongly supported by the presented results.
8.	The principle of 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	Yes, the methodology is described in sufficient detail.

		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 modern scientific research methods, including in situ polymerization, incorporation techniques, and free-radical polymerization. The findings are further supported by advanced computational methods, such as density functional theory (DFT) and molecular dynamics (MD) simulations.
		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 developed methods have been confirmed and applied in official laboratory.
		8.4 Important statements are **confirmed** / partially confirmed / not confirmed by references to current and reliable scientific literature	Yes, Important statements are confirmed.
		8.5 Used literature sources are **sufficient**/not sufficient for a literature review	The literature review is comprehensive. Notably, one review article included in this thesis has been published in a high-impact, peer-reviewed journal, with the PhD candidate as the first author.
9	Practical value principle	9.1 The thesis has theoretical value: 1) **yes;** 2) no	The research provides important theoretical contributions by elucidating how variations in zwitterionic monomer structures—including linear, vinyl, and aromatic heterocyclic types—govern the thermal stability, molecular weight

			distribution, and self-assembly behavior of sulfobetaine polymers. The work further systematizes the fundamental mechanisms underlying fouling resistance, hydration-layer formation, and ion selectivity in zwitterionic membrane systems, establishing clear structure–property–performance relationships. In addition, the study demonstrates how zwitterionic functional groups enhance water transport and selective rejection in membrane materials, thereby deepening the scientific understanding of polymer hydration, charge neutrality, and separation behavior.
		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	From a practical perspective, the thesis demonstrates significant applied value. The findings provide a strong foundation for the development of more efficient and durable membrane materials for water treatment. The demonstrated antifouling properties, enhanced hydration effects, and stable separation performance of zwitterionic polymers offer effective pathways for improving flux recovery, reducing membrane fouling, and increasing rejection efficiency in nanofiltration and ultrafiltration processes.

			Furthermore, these results hold substantial practical importance for the development of next-generation membrane systems capable of addressing critical challenges in desalination, wastewater purification, and industrial water reuse.
		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 methods are entirely novel, as is their application in this area.
10.	The quality of writing and design	Academic writing quality: 1) **high;** 2) average; 3) below average; 4) low.	The thesis demonstrates excellent academic writing, along with a high standard of design and presentation.
11.	Notes on a thesis	I have no additional comments.	
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)	All constituent articles have been published in reputable, international peer-reviewed journals with high impact factors, reflecting both the quality and visibility of the work. Accordingly, I assess the overall scientific standard of the research to be exceptionally high.	
13.	Decision of the official reviewer (pursuant to paragraph 28 of the present Model Regulations)	The thesis, structured as a cohesive series of articles, demonstrates strong scientific rigor, originality, and intellectual coherence. Its findings make a meaningful contribution to the field, offering significance both in advancing fundamental scientific understanding and in their practical applicability. On this basis, I	

		confidently recommend that Ms. Arshyn Zhengis be awarded the degree of Doctor of Philosophy in Chemistry.	

Official Reviewer:

Head of the International R&D Center for Advanced Functional Materials and Their Composites of the Department of Chemical Processes and Industrial Ecology of the Kazakh National Research Technical University named after K.Satbayev, candidate of technical Sciences, associate professor

(signature) **Sana K. Kabdrakhmanova**

Горно-металлургический институт им. О.А. Байконурова

Подпись Kabdrakhmanova S.

Заверяю: Главный менеджер Горно-металлургического института им. О.А. Байконурова НАО «КазНИТУ им. К.И. Сатпаева»

Abilclaeva

ФИО подпись, дата