NAZARBAYEV UNIVERSITY
SCHOOL OF ENGINEERING AND DIGITAL SCIENCES

08.12.2025

To the Faculty of Chemistry and Chemical Technology,
Al-Farabi Kazakh National University

Review

I am delighted to congratulate Arshyn on the outstanding scientific achievements presented in her dissertation, *"Preparation of a Novel Multifunctional Zwitterionic Polymeric Membrane."* Organized as a cohesive compilation of published research articles, this dissertation offers a comprehensive, rigorous, and innovative exploration of zwitterionic polymer science and its applications in advanced membrane technologies. Arshyn's work not only enriches the fundamental understanding of zwitterionic materials but also makes substantial practical contributions to the development of modern water purification and environmental remediation solutions.

The first article, *"Preparation of Zwitterionic Sulfobetaines and Study of Their Thermal Properties and Nanostructured Self-Assembling Features,"* published in *Nanomaterials*, establishes the molecular foundation of the dissertation through the synthesis and characterization of four structurally distinct sulfobetaine-based polyzwitterions. Using a robust combination of GPC, TGA, DSC, TEM, and zeta potential analyses, demonstrates how subtle structural modifications result in pronounced differences in thermal stability, glass transition behavior, and pH-responsive self-assembly patterns. These findings provide essential insights into the structure–property relationships governing polyzwitterion performance and serve as a theoretical basis for the membrane engineering strategies developed later in the dissertation.

The second article, *"Zwitterionic SBMA-based Nanofiltration Membranes: Synthesis Techniques, Antifouling Mechanisms, and Future Perspectives,"* published in *Polymer*, highlights Arshyn's strong capacity for conceptual synthesis and critical scientific evaluation. This comprehensive review presents a detailed examination of membrane fouling phenomena including organic, inorganic, colloidal, and biofouling types while explaining the fundamental chemical and morphological features of sulfobetaine methacrylate (SBMA). Arshyn thoroughly discusses antifouling mechanisms such as hydration-layer formation, steric repulsion, and electroneutrality, and evaluates three major membrane modification techniques: surface coating, surface grafting, and physical blending. By linking structural characteristics with performance outcomes and identifying limitations and future opportunities such as hybrid systems and scalability pathways, this article establishes the broader scientific and technological context of her dissertation and positions Arshyn as a knowledgeable and insightful contributor to the membrane research community.

The third article, *"Zwitterion–MOF Functional Interface Enabling Robust Ion and Dye Rejection in Water Filtration,"* published in *ACS Applied Materials & Interfaces*, represents the practical culmination of Arshyn's research efforts. In this study, she engineers a hierarchically structured PAN–PVP membrane integrated with ZIF-8 nanoparticles and SBMA, achieving a multifunctional design with significant real-world utility. Comprehensive characterization using SEM, FTIR, XRD, XPS, and zeta potential analysis confirms the stable incorporation and chemical compatibility of the ZIF-8/SBMA system. The resulting membrane exhibits excellent water flux, high rejection efficiencies for heavy metals and dyes, and remarkable operational durability across repeated filtration cycles. This work effectively demonstrates the translation of fundamental zwitterionic polymer insights into a robust, scalable, and high-performance membrane platform tailored for advanced water purification applications.

Taken together, these three studies demonstrate Arshyn's exceptional ability to unify fundamental polymer chemistry, membrane engineering, and advanced analytical and simulation techniques into a coherent and impactful body of scientific work. She exhibits impressive scientific independence through well-designed experiments, sophisticated characterization and data interpretation, strong theoretical grounding, innovative material design, and a clear and consistent linkage between molecular structure and membrane performance. Her dissertation significantly advances the understanding of zwitterionic materials and introduces practical membrane systems with high flux, selectivity, antifouling performance, and structural robustness - addressing critical global challenges in water purification.

Arshyn's creativity, perseverance, and technical expertise have been integral to the success of our research endeavors. She conducts her work with exceptional rigor and professionalism, demonstrating both the skill and scientific maturity expected of an emerging leadera in the fields of polymer science and membrane engineering. I am confident that her future scientific contributions will continue to reflect the same level of excellence, insight, and innovation.

Please feel free to contact me if you have any further questions or require additional information.

Sincerely,

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