

REVIEW

of the official reviewer for the dissertation work of **Ayazbaeva Aigerim Erlanovna**

on the topic “**Synthesis and characterization of polyampholyte nano- and microgels based on acrylamide derivatives**”, submitted for the degree of **Doctor of Philosophy PhD**

specialty 8D07108 – Basic processes for the synthesis and production of new organic and polymeric materials

№ п/п	Criteria	Eligibility (must be noted one of the answer options)	Justification of the position of the official reviewer
1.	The topic of the dissertation (as of the date of its approval) corresponds to directions of scientific development and/or government programs	Compliance with priority areas of scientific development or government programs: 1) The dissertation 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 dissertation was completed within the framework of another state program (indicate the name of the program) 3) The dissertation corresponds to the priority direction of scientific development, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction)	1. The work was conducted in the frame of projects "Synthesis and Study of Thermo- and Salt-Sensitive Polyampholyte Nano- and Microgels" for the period 2020-2022 (AP0885552) and "Development of New Thermal and Salt-Resistant Amphoteric Terpolymers for Enhanced Oil Recovery" for the period 2021-2023 (AP09260574) funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan. 2. It was partly funded by the Horizon 2020 research and innovation program of the European Union Maria Sklodowska-Curie (grant agreement 823883-MSCA-RISE-2018 NanoPol). 3. Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technology, safe products and structures. <i>3.15. Polymer materials with special properties.</i> 10. Scientific research in the field of natural sciences. <i>10.3. Basic and applied research in chemistry</i> <i>Note: Not stated in the dissertation.</i>
2.	Importance for science	The work does/does not make a significant contribution to science and its importance is/is not well disclosed	The work is devoted to the study of the principles of synthesis of stimulus-sensitive polymer amphoteric materials of linear and spatially cross-linked structure based on thermosensitive copolymers of N-isopropylacrylamide (NIPAM) with cationic ((3-acrylamidopropyl) trimethylammonium chloride (APTAC)) and anionic (sodium salt of 2-acrylamido-2-methylpropanesulfonate (AMPS)) monomers, hydrophilic copolymers of acrylamide (AAm) with the above-mentioned charged comonomers, as well as their combinations with the formation of trifunctional macromolecules. The work makes a significant contribution to the science of stimulus-sensitive polymer aggregates or their linear forms from the point of view of controllability of the process of changing the hydrodynamic dimensions of linear sections of macromolecular

			<p>chains between physical or chemical cross-linking points depending on the following parameters:</p> <ol style="list-style-type: none"> 1) stoichiometry of the functional groups of comonomers responsible for thermal and salt sensitivity; 2) the ratio of positively and negatively charged functional groups of co-monomers and their distribution in the main polymer backbone of poly-N-isopropylacrylamide (PNIPAAm) and polyacrylamide (PAAm), corresponding to a “reflex” reaction to changes in environmental conditions, such as temperature and ionic strength of the solution; 3) a theoretical assessment was carried out for the influence of the stoichiometric composition of oppositely charged functional groups of the monomers in the structure of linear and spatially cross-linked macromolecular chains of PAAm and PNIPAAm on their hydrodynamic sizes. 4) the data are presented on the potential possibility of using nano- and microgels of amphoteric polymers obtained in the work for the controlled release of drugs from their matrix with a prolonging effect using the example of a dye-polymer matrix model system. 5) the high efficiency of using synthesized nano- and microgels is shown to improve reducing the degree of water cut in oil-bearing horizons and increasing the oil recovery factor.
3.	Principle of independence	<p>Level of independence:</p> <ol style="list-style-type: none"> 1) High; 2) Average; 3) Low; 4) No independence 	<p>3.1. The author of the dissertation showed a high level of independence in setting problems, methods of solving and interpreting the results obtained. A competent selection of the component composition of the studied amphoteric nano- and microgels was carried out to solve the problems posed in the dissertation.</p>
4.	The principle of internal unity	<p>4.1 Justification of the relevance of the dissertation:</p> <ol style="list-style-type: none"> 1) Justified; 2) Partially justified; 3) Not justified. 	<p>4.1. The relevance of the dissertation work is justified by the following statements:</p> <ol style="list-style-type: none"> 4.1.1. the possibility and importance of using thermo- and salt-sensitive amphoteric nano- and microgels in medical practice for the development of polymer systems for controlled targeted delivery of biologically active compounds and drugs to injured organs. 4.1.2. Temperature and salt sensitive polyampholyte microgels can also be used as suitable thickeners in oil reservoirs with high temperatures and salinity to increase oil recovery.

	<p>4.2 The content of the dissertation reflects the topic of the dissertation:</p> <ol style="list-style-type: none"> 1) Reflects; 2) Partially reflects; 3) Does not reflect. 	<p>4.2.1. The content of the work fully reflects the topic of the dissertation in accordance with the assigned tasks and the achievement of the final result in relevance to these objectives.</p>
	<p>4.3 The purpose and objectives correspond to the topic of the dissertation:</p> <ol style="list-style-type: none"> 1) correspond; 2) partially correspond; 3) do not correspond. 	<p>4.3.1. The purpose and objectives of the dissertation are fully correspond to the topic of the dissertation.</p>
	<p>4.4 All sections and provisions of the dissertation are logically interconnected:</p> <ol style="list-style-type: none"> 1) completely interconnected; 2) the relationship is partial; 3) there is no relationship. 	<p>4.4.1. All sections and provisions of the dissertation are logically completely interconnected.</p> <p>The dissertation includes a list of abbreviations and symbols, an introduction in which emphasizes the relevance of the research, the level of development of the scientific direction, achievements and shortcomings, defines the purpose and objectives of the research, conclusions based on the research results, shows the scientific novelty of the work and scientific and applied significance of the obtained results.</p>
	<p>4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with known solutions:</p> <ol style="list-style-type: none"> 1) there is a critical analysis; 2) partial analysis; 3) the analysis does not represent one's own opinions, but quotes from other authors 	<p>4.5.1. This research allows the development of a new class of cross-linked amphoteric polymer structures characterized by stimulus-responsive behavior, self-healing properties, reliable adhesion, mechanical flexibility and strength. It was established that long-range Coulomb forces between opposite charges along the polymer chain are the determining factors for conformational and volume-phase changes in highly charged polyampholyte gels.</p> <p>The work is based on a critical analysis of deservedly recognized scientific achievements in this area with references to relevant authoritative publications of other authors that do not contradict the data obtained in the dissertation.</p>

5.	The principle of scientific novelty	<p>5.1 Are the scientific results and provisions new?</p> <p>1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>5.1.1. The obtained results and established statements are completely new, since the work for the first time describes the synthesis and mechanism of formation of trifunctional amphoteric polymers of a linear and slightly cross-linked structures. Moreover, the main polymer backbone consists of thermosensitive poly-N-isopropylacrylamide along which the oppositely charged cationic and anionic monomer units responsible for salt sensitivity are situated.</p> <p>A detailed study of the influence of the hydrophilic-lipophilic balance (GLB) of the initial reaction mixture during emulsion polymerization of linear and three-dimensional rarely cross-linked polyelectrolytes and polyampholytes was carried out. It has been shown that an increase of surfactant (TWEEN80, SPAN 80) content causes a decrease in the average hydrodynamic sizes of nano- and microgels with a mono- and bimodal distribution.</p>
		<p>5.2 Are the findings of the thesis new?</p> <p>1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>5.2.1. The conclusions of the dissertation are completely new.</p> <p>5.2.1.1. By means of free radical polymerization method a new class of thermo- and salt-sensitive amphoteric nano- and microgels of a linear and spatial structure with adjustable HLB was synthesized.</p> <p>5.2.1.2. The hydrodynamic sizes of the resulting amphoteric nano- and microgels as well as their surface charge, rheological, sorption properties and structural organization were determined depending on the synthesis conditions, temperature and ionic strength of the solution.</p> <p>5.2.1.3. The results obtained indicate that the suspension of amphoteric microgels based on PAAm derivatives with charged functional groups of APTAC and AMPS does not clog the micropores of the rock and can be used to extract oil.</p>
		<p>5.3 Technical, technological, economic or management solutions are new and justified:</p> <p>1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>5.3.1. Technical, technological, economic or management solutions are completely new and justified.</p> <p>5.3.1.1. The possibility of using synthesized amphoteric nano- and microgels as carrier matrices for drugs has been established. It has been shown that the sorption of drugs can occur both on the surface and in the bulk of polymer hydrogels, and the degree of desorption can be controlled by the ionic strength of the solution or the ambient temperature.</p> <p>5.3.1.2. The modeling results of polymer flooding of oil reservoirs using amphoteric nano- and microgels obtained in the work show high economic efficiency in reducing the degree of water cut in the</p>

			oil-bearing horizon and increasing the oil recovery factor. 5.3.1.3. The mechanism of formation of amphoteric polymer nano- and microgels derived from PNIPAAm and PAAm is fully disclosed and presented which is confirmed by a set of modern physicochemical methods of analysis.
6.	Validity of the main conclusions	All main conclusions are/are not based on scientific point of evidence or are reasonably well substantiated	All scientific conclusions are fully justified from a scientific point of view and are based on an analysis of modern ideas in the field of polymer chemistry and trends in the development of new classes of composite materials with specified properties.
7	Основные положения, выносимые на защиту Main statements submitted for defense	It is necessary to answer the following questions for each statement separately: 7.1 Is the statement proven? 1) proven; 2) rather proven; 3) 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) average; 3) wide. 7.5 Is it proven in the article? 1) yes; 2) no.	7.1. Proven: 7.1.1. Synthesis, characterization and properties of polyampholyte nanogels based on NIPAM-APTAC-AMPS obtained via free-radical polymerization; 7.1.2. Study of thermal and salt sensitivity of nanogels, selection of suitable nanogels for immobilization of model drugs – anionic (methyl orange) and cationic (methylene blue) dyes. study of release kinetics of model drugs from the nanogel matrix in dependence of temperature and salt composition; 7.1.3. Synthesis, characterization and properties of polyampholyte microgels based on AAm-APTAC-AMPS obtained via inverse emulsion polymerization. 7.2.No. All statements are irrefutable and scientifically proven 7.3.1. All statements are new and valuable for providing next studies in the field of synthesis new polymeric stimuli sensitive systems. 7.4.3. Wide. The level of application is high since the amphoteric nano- and microgels obtained in the work can be used in medicine as prolongers of the action of drugs in a polymer matrix and oil production to increase the oil recovery coefficient. 7.5.1. Yes. All obtained results are confirmed by publications in highly rated journals. The main results of the study are presented in 3 articles published in journals from the list approved by the Committee for Control in the Sphere of Education and Science of the Republic of Kazakhstan, 2 articles were included in the Scopus and Web of Science database. 3 abstracts of reports were published in proceedings of international conferences. Articles published in journals from the list approved by the Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Education and Science of

			<p>the Republic of Kazakhstan:</p> <ol style="list-style-type: none"> 1. Ayazbayeva A.Ye., Shakhvorostov A.V., Seilkhanov T.M., Aseyev V.O., Kudaibergenov S.E. Synthesis and characterization of novel thermo- and salt sensitive amphoteric terpolymers based on acrylamide derivatives // Bulletin of the University of Karaganda – Chemistry. - 2021. - Vol.104, №4. - P.12-20. doi.10.31489/2021Ch4/9-20; 2. Ayazbayeva A.Ye., Shakhvorostov A.V., Kudaibergenov S.E. Temperature and Salt Responsivity of Anionic, Cationic and Amphoteric Nanogels Based on NIsopropylacrylamide, 2-Acrylamido-2-Methyl-1-Propanesulfonic Acid Sodium Salt and (3-Acrylamidopropyl) Trimethylammonium Chloride // Bulletin of the University of Karaganda – Chemistry. — 2022. - Vol.108, №4. - P. 14-24. doi.10.31489/2022Ch4/4-22-15; 3. Ayazbayeva A.Ye., Nauryzova S.Z., Aseyev V.O., Shakhvorostov A.V. Immobilization of Methyl Orange and Methylene Blue within the Matrix of ChargeImbalanced Amphoteric Nanogels and Study of Dye Release Kinetics as a Function of Temperature and Ionic Strength // Bulletin of the University of Karaganda Chemistry. - 2022. - Vol.107, №3. - P. 127-140. doi.10.31489/2022Ch3/3-22-4. <p>Articles indexed in the Scopus and Web of Science:</p> <ol style="list-style-type: none"> 1. Ayazbayeva A.Y., Shakhvorostov A.V., Gussenov I.S., Seilkhanov T.M., Aseyev V.O., Kudaibergenov S.E. Temperature and Salt Responsive Amphoteric Nanogels Based on N-Isopropylacrylamide, 2-Acrylamido-2-methyl-1-propanesulfonic Acid Sodium Salt and (3-Acrylamidopropyl)Trimethylammonium Chloride //Nanomaterials — 2022. — Vol.12. — 2343. doi.10.3390/nano12142343; 2. Ayazbayeva A., Baddam V., Shakhvorostov A., Gussenov I., Aseyev V., Yermagambetov M., Kudaibergenov S. Amphoteric nano- and microgels with acrylamide backbone for potential application in oil recovery // Polymers for advanced technologies. - 2023. doi.10.1002/pat.6182.
8.	Principle of reliability Reliability of sources and information provided	8.1. The choice of methodology is justified or the methodology is described in sufficient detail 1) yes; 2) no.	8.1.1. Yes. The choice of research methodology is fully justified and described in the experimental part of the dissertation in detail. The essence of the work is revealed in next stages: it begins from the synthesis stage, followed by the disclosure of the polymerization reaction mechanism, and the assessment of the hydrodynamic size

			of macromolecular chains in aggregated nano- and microcompositions under the influence of temperature and ionic strength of the solution. In addition, the electrical, surface-active and sorption parameters of the obtained linear and rarely cross-linked amphoteric terpolymers are studied. The totality of the data obtained provides extensive information on the physicochemical properties of aggregated amphoteric derivatives of polyacrylamide and poly-N-isopropylacrylamide polymers and the potential of their applicability for creating specific applied aspects.
		8.2 The results of the dissertation work were obtained using modern scientific methods research and processing techniques and data interpretation using computer technologies: 1) yes; 2 no.	8.2.1.Yes. The results on the identification and study of polyelectrolyte and polyampholyte nanoand microgels by NMR and FTIR spectroscopy, SEM, TEM, dynamic laser light scattering, zeta potential, TGA and DTA. Data processed using computer technology were not detected, most likely due to the lack of such tasks.
		8.3. Theoretical conclusions, models, identified relationships and patterns are proven and confirmed by experimental research: 1) yes; 2) no.	8.3.1.Yes. Theoretical conclusions, models, identified relationships and patterns are proven and confirmed by experimental research. The composition of polyampholyte nanogels was determined by FTIR, ¹ H NMR spectroscopy, and elemental analysis. The surface morphology was studied using SEM. The method of dynamic light scattering and zeta potential was used to determine the average hydrodynamic radius and zeta potential of amphoteric macromolecules. Thermal stability was studied by TGA and DTA methods.
		8.4 Important statements are confirmed/partially confirmed/not confirmed by references to current and reliable scientific literature	Part 3. Results and discussion. To interpret data on the synthesis method, identify the composition of resulting nano- and micro-sized amphoteric hydrogels and determine their physicochemical characteristics and applied properties, references to publications of leading experts in this field were used. In particular, this concerns works [76-88], [103,129,134-138] and etc.
		8.5 Literature used sufficient/not sufficient for a literary review	The list of cited literature consists of 146 references, most of which date from the last decade.
9.	Principle of practical value	9.1 The dissertation has theoretical significance: 1) yes; 2) no.	9.1.1. Yes. The dissertation has great theoretical significance according to the following conclusions: Variation of phase separation points under changing of temperature and ionic strength of the solution depending on the component composition of nano- and microgels. The possibility of associative aggregation of amphoteric macromolecules with a change of the structure of associated domains of

			<p>nano- and microparticles of the gel with compaction of their hydrophobic core and the formation of an external charged shell according to the theoretical model of a “globule with an edge”, characteristic of linear interpolymer systems.</p> <p>Mono- and bimodal distribution of polyampholyte mono- and microgel particles has been established according to their sizes when changing the HLB of the reaction medium during emulsion polymerization.</p>
		<p>9.2 The dissertation has practical significance and there is a high probability of applying the results obtained in practice:</p> <p>1) yes; 2) no</p>	<p>9.2.1. Yes. Based on the data obtained, a microgel with the composition [AAm]-[APTAC]-[AMPS] = 80-10-10 mol.% was chosen as the optimal object of study for use in experiments on cores and a physical model of the reservoir to assess the oil-displacing (oil-producing) capacity under reservoir conditions.</p>
		<p>9.3 Are the practice suggestions new?</p> <p>1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>9.3.1. Completely new. Thermo- and salt-sensitive amphoteric nano- and microgels proposed for practical use are important for use in medicine for the controlled release of drugs into the diseased organs from the volume of the polymer matrix and also for regulating the filtration-capacitive parameters of oil-bearing horizons.</p>
10	Quality of writing and design	<p>Quality of academic writing:</p> <p>1) high; 2) average; 3) below average; 4) low</p>	<p>10.1. Quality of academic writing is high. The presentation of the material, description and explanation of the results obtained are given in a competent academic style. Drawings and other demonstration materials are designed in accordance with the requirements for dissertation works.</p>

Conclusion: Thus, one can conclude that the work on the topic “Synthesis and characterization of polyampholyte nano- and microgels based on acrylamide derivatives” was made at a high professional level both from the point of view of theory and practical significance, as noted above. The author of the work, Ayazbayeva Aigerim Yerlanovna, deserves to be awarded the degree of Doctor of Philosophy (PhD) in specialty 8D07108 – “Basic processes for the synthesis and production of new organic and polymeric materials.

During the review of the dissertation work a number of notes were identified.

- How to explain the different behavior of changes in the electrokinetic potential for charged PNIPAAm copolymers depending on their concentration (Fig. 6, p. 36). It can be seen that the standard deviation of the ξ -potential for the PNIPAAm-APTAC copolymer is +10 mV, which corresponds to a deviation of up to 30% from the main value of the ξ -potential of 30 mV (30 ± 10 mV). This deviation exceeds the acceptable limits of measurement accuracy. For the anionic copolymer PNIPAAm-AMPS the deviation from the average value of the ξ -potential is acceptable (-54 ± 3 mV), but how can explain the sharp decrease its value from -5 to -54 mV when the copolymer concentration changes from 0.01% to 0.025% with further stabilization of the ξ -potential practically unchanged? In the experimental part (paragraphs 2.11 and 2.12., p. 32) the accuracy of determining the zeta-potential on a Zeta-sizer Nano ZS 90 is not presented.
- Page 46. The correct expression would be “pushing out” charged functional groups from the core of hydrophobic aggregates rather than “migrate...”). Since we are talking about the charge of the monomer unit associated with the main polymer chain then only free ions (counterions) can migrate. It would be

advantageous to supplement the explanation of the obtained results of aggregation of amphoteric nano- and micro-sized polymer gels using a thermodynamic approach taking into account the entropic and enthalpy contributions to the Gibbs free energy.

3. Is it possible to evaluate the increase in oil recovery factor by using amphoteric microgels for highly mineralized water-oil emulsion under reservoir conditions?
4. There are some editorial comments.
 - 4.1. Page 32. Paragraph 2.12. zeta potential denoted as (μ)
 - 4.2. Page 51. The content of the chapter 3.3. Synthesis and characterization of polyampholyte nanogels based on NIPAM-APTAC and NIPAM-AMPS does not correspond to the title. The chapter discusses the behavior of cationic and anionic polymers, but not amphoteric polyelectrolytes. Correct the word "amphoteric" to "cationic and anionic"

However, these comments are advisory in nature and do not reduce the value and scientific and practical significance of the dissertation work.

Reviewer:
DrSci., Prof.



Mamytbekov Galymzhan Kulamkadyrovich