

ANNOTATION

for the dissertation work on the topic «Development of methods for the parallel separation of cationic and anionic components from hydrometallurgical process solutions» for the degree of Doctor of Philosophy (PhD) in the specialty 8D05301 - "Chemistry" by Dyussembayeva Gulnur Toktargazinovna

Research topic: «Development of methods for the parallel separation of cationic and anionic components from hydrometallurgical process solutions»

The purpose of the study is to:

Development of interpolymer systems based on functional cross-linked polymers for the separation of cationic and anionic components in model solutions and investigation of sorption processes in technological solutions.

Research objectives:

1. To develop KU-2-8 (H^+)-AV-17-8(OH^-), KU-2-8 (H^+)-P4VP and gPMAA-gP4VP interpolymer systems at various molar ratios (X:Y).
2. To investigate the electrochemical and conformational properties of the KU-2-8(H^+)-AV-17-8(OH^-), KU-2-8(H^+)-P4VP and gPMAA-gP4VP interpolymer systems resulting from their remote interactions.
3. To develop methods for separating gold-bearing compounds formed during heap leaching through modeling using interpolymer systems based on individual ion exchangers and hydrogels.
4. To investigate the sorption process in technological solutions using KU-2-8(H^+)-AV-17-8(OH^-) interpolymer systems.

Research methods:

theoretical: a literature review was conducted on the physicochemical properties of cationic and anionic components in technological solutions of hydrometallurgy, as well as methods for their parallel extraction.

experimental methods: electrochemical and gravimetric, inductively coupled plasma atomic emission spectroscopy, Scanning electron microscope, IR spectroscopy, thermogravimetry and differential scanning calorimetry.

The main provisions (proven scientific hypotheses and other conclusions that are new knowledge) submitted for defense

1. A change in the initial state of one of the components in an interpolymer system leads to a change in the electrochemical behavior of ion exchangers and interpolymer systems. Electrochemical and conformational changes resulting from the remote interaction of industrial ion exchangers (KU-2-8 (H^+), AV-17-8 (OH^-)) and individual hydrogels (PMAA, P4VP) were studied. In the KU-2-8(H^+)-AV-17-8(OH^-) interpolymer system at a ratio of (4:2), the specific conductivity of the aqueous medium reached a maximum after 6 hours, amounting to 7.0 $\mu S/cm$. This value is significantly higher than the specific conductivity of the initial cation exchanger at a ratio of (6:0), which was 2.55 $\mu S/cm$. For the KU-2-8–P4VP system, the maximum recorded conductivity value

was 5.5 $\mu\text{S}/\text{cm}$, which also indicates an increase compared to the initial conductivity value (1.56 $\mu\text{S}/\text{cm}$) at a ratio of (6:0). The swelling degree of this system was $K_{\text{sw}}(\text{gPMAA}) = 5.45 \text{ g/g}$. The swelling degrees of the rarely cross-linked polymer hydrogels in their individual states were $K_{\text{sw}}(\text{gPMAA}) = 20.65 \text{ g/g}$ and $K_{\text{sw}}(\text{P4VP}) = 3.27 \text{ g/g}$.

2. At a certain ratio of acidic and basic ion exchangers, a significant increase in the sorption of metal ions was observed compared to the initial ion exchangers. In the KU-2-8(H^+)-AV-17-8(OH^-) interpolymers system at a ratio of (3:3) after 48 hours, the maximum sorption of Au(I) and Fe(II) ions reached 97.00% and 44.33%, respectively, which is significantly higher compared to the performance of the initial cation exchanger (6:0), which stood at 4.70%. The distribution coefficient was $K_d(3:3)_{\text{Au}} = 3,233 \text{ ml/mg}$. Partition coefficient $\beta_{\text{Au/Fe}} = 40.62$. The degree of desorption was $D_{\text{dAu}} = 98.00\%$.

3. The sorption degree of the initial hydrogels was 7.70%. Meanwhile, in the gPMAA-gP4VP intergel system at a ratio of (3:3) during a 6-hour interaction, the sorption of iron ions reached 90.1%, while the sorption of gold ions was 4.6%. The distribution coefficient was $K_d(3:3)_{\text{Au}} = 2,95 \text{ ml/mg}$ and $K_d(3:3)_{\text{Fe}} = 16,920 \text{ mL/mg}$. Partition coefficient $\beta_{\text{Au/Fe}} = 0,1749$.

4. The optimal method for recovering ions from technological solutions was determined using KU-2-8(H^+)-AV-17-8(OH^-) interpolymers systems formed on the basis of a strongly acidic cation exchanger and a strongly basic anion exchanger. It was established that when the fraction of the anion exchanger predominates in the system (at ratios of 1:5 and 0:6), the maximum sorption activity toward gold (Au^+) and iron (Fe^{2+}) ions is observed, ranging from 90% to 97%. Conversely, under conditions of cation exchanger excess (at ratios of 6:0 and 5:1), copper (Cu^{2+}), cobalt (Co^{2+}), nickel (Ni^{2+}), and zinc (Zn^{2+}) ions are sorbed with high intensity, reaching 95% on the individual cation exchanger.

Justification of the novelty and significance of the results obtained and their compliance with the directions of scientific development or government programs:

1. As a result of the conducted work, KU-2-8(H^+)-AV-17-8(OH^-), KU-2-8(H^+)-P4VP, and gPMAA-gP4VP interpolymers systems with various molar ratios (X:Y) were developed for the first time.

2. For the first time, as a result of remote interaction, the electrochemical and conformational properties of the interpolymers systems KU-2-8(H^+)-AB-17-8(OH^-), KU-2-8(H^+)-P4VP were studied.

3. For the first time, methods for the separation of gold-bearing compounds formed during heap leaching were investigated through modeling using interpolymers systems based on individual ion exchangers and hydrogels.

4. For the first time, the sorption process in technological solutions was investigated using KU-2-8(H^+)-AV-17-8(OH^-) interpolymers systems.

The dissertation work was carried out within the framework of performed under the state program-targeted financing “Synthesis and creation of technologies of multifunctional action fertilisers, compositions, preparations and materials for using on desert and degraded lands” (BR 21882220, 2023–2025) and

«Fundamental bases for obtaining innovative environmentally safe multifunctional chemical products and materials» (BR 27101179, 2024–2026) at the JSC “Institute of Chemical Sciences named after. A.B. Bekturov”, in the laboratory of synthesis and physicochemistry of polymers.

Description of the doctoral student's contribution to the preparation of each publication:

The main results of the dissertation research were published in 10 publications, including: 2 articles in international scientific journals included in the Scopus scientometric database (Q) (Polymers, percentile 87%, Molecules percentile 89%):

1. Selective Gold Ion Sorption from Iron-Containing Solution Using an interpolymer System of Industrial Ion Exchangers. Polymer. – 2025. – 17(20). 2808. (Dyussebayeva G.T 75%, co-authors Jumadilov T.K., Grazulevicius J.V., Mukatayeva Zh.S., Khimersen Kh., Totkhuskyzy B.)

2. Selective Sorption of Gold and Iron Ions in the PMAA-P4VP Intergel System. Molecules. – 2026. – 31(10). 1583. (Dyussebayeva G.T 80%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V., Khimersen Kh.)

7 articles published in publications recommended by the Committee for quality assurance in the field of Science and higher education of the MSHE of the Republic of Kazakhstan:

1. Features of remote interaction between hydrogels of polymethacrylic acid and poly-2-methyl-5-vinylpyridine. Reports of the academy of sciences of the Republic of Kazakhstan «Halyk» Private Foundation. – 2024. – №1 (349). – P. 155-166. (Dyussebayeva G.T. 80%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V., Saparbekova I.S.)

2. Influence of the effect of remote interaction of the interpolymer system KU-2-8: AV-17-8. Chemical Journal of Kazakhstan. – 2024. – №4 (88). – P. 25-34. (Dyussebayeva G.T 85 %, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V.)

3. Investigation of electrochemical and conformational properties of interpolymer systems of cationite KU-2-8 and anionite P4VP. – 2024. – №4 (352). – P. 146-156. (Dyussebayeva G.T 85%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V.)

4. Characteristics of mutual activation of an intergel system based on hydrogel polymethacryl acid and poly-4-vinyl pyridine. Chemical Journal of Kazakhstan. – 2024. – №2 (86). – P. 94-104. (Dyussebayeva G.T 80 %, co-authors Jumadilov T.K., Mukatayeva Zh.S., Suleimenova M.T., Grazulevicius J.V.)

5. Features of gold ion extraction by the interpolymer system KU-2-8 and poly-4-vinylpyridine. Chemical Journal of Kazakhstan. – 2025. – №1 (89). – P. 98-108. (Dyussebayeva G.T 85%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V.)

6. Changing the degree of connection of polymer chains with gold and iron ions in the interpolymer system KU-2-8-P4VP. Chemical Journal of Kazakhstan. –

2025. – №3 (91). – P. 34-43. (Dyussebayeva G.T 80 %, co-authors Jumadilov T.K., Mukatayeva Zh.S., Khimersen Kh., Grazulevicius J.V.)

7. Features of the interaction of intergel systems based on polyacrylic acid and poly-2-methyl-5-vinylpyridine with gold ions. Chemical Journal of Kazakhstan. – 2026. – №1 (93). – P. 60-68. (Dyussebayeva G.T 75%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Khimersen Kh., Erzhet B., Grazulevicius J.V.)

Abstracts of the papers were published in the proceedings of international scientific and practical conferences, including those held in neighboring and more distant foreign countries:

«Remote interaction of an intergel system based on polymethacrylic acid and poly-2-methyl-5-vinylpyridine». Materials International scientific and practical conference "Modern aspects of chemical science and chemical education: Theory and practice" dedicated to the 70th anniversary of Doctor of Chemical Sciences, Professor, Academician of the MAIN and NAS Higher School of Economics N.A. Bektenov and Doctor of Chemical Sciences, Professor Corresponding member of the Russian Academy of Sciences G.I. Meirova. – Almaty. – 2024. – P. 143-144. (Dyussebayeva G.T 80%, co-authors Jumadilov T.K., Mukatayeva Zh.S., Grazulevicius J.V., Tatrishvili T.)

Structure and scope of work.

The dissertation work consists of standard sections: normative references, notations and abbreviations, introduction, literature review, experimental part, experimental results and their discussion, list of references and appendix.