ЕҢБЕК ҚЫЗЫЛ ТУ ОРДЕНДІ
«Ә. Б. БЕКТҰРОВ АТЫНДАҒЫ
ХИМИЯ ҒЫЛЫМДАРЫ ИНСТИТУТЫ»
АКЦИОНЕРЛІК ҚОҒАМЫ

ҚАЗАҚСТАННЫҢ ХИМИЯ ЖУРНАЛЫ

ХИМИЧЕСКИЙ ЖУРНАЛ КАЗАХСТАНА

CHEMICAL JOURNAL of KAZAKHSTAN

АКЦИОНЕРНОЕ ОБЩЕСТВО
ОРДЕНА ТРУДОВОГО КРАСНОГО ЗНАМЕНИ
«ИНСТИТУТ ХИМИЧЕСКИХ НАУК
им. А. Б. БЕКТУРОВА»

4 (64)

ОКТЯБРЬ – ДЕКАБРЬ 2018 г.

ИЗДАЕТСЯ С ОКТЯБРЯ 2003 ГОДА

ВЫХОДИТ 4 РАЗА В ГОД

АЛМАТЫ
2018

UDC 541.132/.132.4:541.49

T. K. JUMADILOV, R. G. KONDAUROV, S. A. KHAKIMZHANOV, A. M. IMANGAZY

«Institute of Chemical Sciences named after A. B. Bekturov» JSC,
Almaty, Republic of Kazakhstan

INFLUENCE OF LONG-RANGE EFFECT BETWEEN POLYMETHACRYLIC ACID AND POLY-4-VINYLPYRIDINE HYDROGELS ON THE SORPTION ABILITY TO LANTHANUM IONS

Abstract. The phenomenon sorption of lanthanum ions by polymethacrylic acid hydrogel (gPMAA) and poly-4-vinylpyridine hydrogel (gP4VP) intergel system was studied. It was established that the structure of the basic hydrogel significantly influence the self-organization of the PMAA hydrogels. Hydrogels mutual activation in an aqueous medium, particularly dependencies of swelling coefficient, specific electric conductivity and pH of water solutions are studied. The lanthanum ions extraction degree by individual hydrogels PMAA and P4VP was 71% and 59%, respectively. At ratio4:2 (67% of gPMAA-33% gP4VP), up to 90% lanthanum ions were recovered. The individual PMAA and P4VP polymer hydrogels have relatively low values of the polymer chain binding degree 1.34% and 0.79%, respectively.

The obtained results indicate the possibility of creating selective intergel systems for lanthanum ions production.

Keywords: intergel system, sorption, remote interaction, La^{3+} ions, hydrogels, polymethacrylic acid, poly-4-vinylpyridine.

Introduction. Rare-earth elements are used in various industries: instrument making, radio electronics, machine building, nuclear engineering, metallurgy, chemical industry, etc. Lanthanum, cerium, praseodymium, neodymium are widely used in the glass industry in the form of oxides and other compounds [1]. These elements increase the translucence of the glass. Rare-earth elements are part of special-purpose glasses that transmit infrared rays and absorb ultraviolet rays, and heat-resistant glass [2]. Rare earth elements and their compounds are widely distributed in the chemical industry, for example, in the production of pigments, varnishes and paints, certain explosives, special steels and alloys, as degasifiers [3].

Mutual activation of polymer hydrogels leads to significant changes in their electrochemical and conformational properties. It should be noted that in previous studies, the initial polymers were applied in a dry state. Remote interaction is carried out by the following processes: rapid - hydration, ionization, dissociation, association and slow - change in the conformational state of inter-node links. It is obvious that the initial state of the rare-crosslinked hydrogels should influence the rate of interactions in the intergel system (figure 1). Swollen polymers are better subjected to mutual activation due to the fact that the macromolecular coil unfolds during swelling, as a result, the activity of functional groups increases. In connection with this, the purpose of this work was to study the sorption ability of

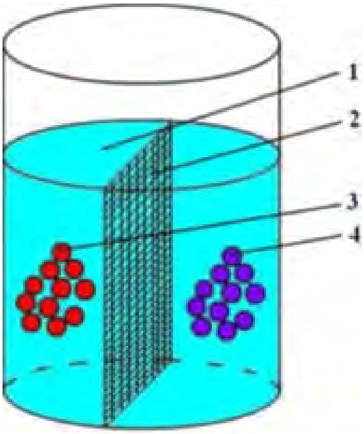


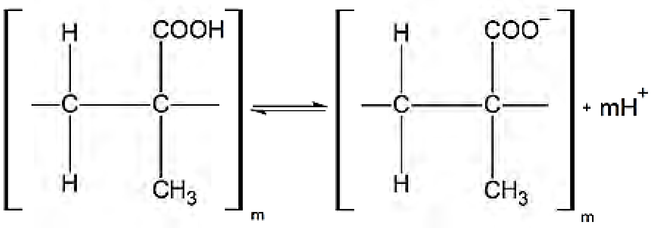
Figure 1 – Intergel system: 1 – solution, 2 – membrane, 3 – acidhydrogel, 4 – base hydrogel. Intergel systems – multicomponent systems, whichconsist of two or more hydrogelsand solution. Importantmoment: there is no direct contactbetween polymers

the gPMAA-gP4VP intergel system consisting of preliminary swollen hydrogels with respect to lanthanum ions.

As a result of previous studies [4-7], it was established that the remote interaction of polymer hydrogels in intergel systems leads to significant changes in the conformational state as a result of their self-organization.In connection with this, the aim of this work was to study the effect of the second component (polybase) on the self-organization of polymer hydrogels of polymethacrylic acid in the intergel system, as well as the study of the sorption properties of the gPMAA-gP4VP intergel systems with respect to lanthanum ions**.**

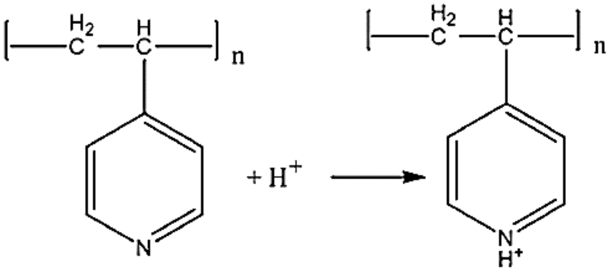
Two main reactions occur in intergel systems:

1. Acid hydrogel dissociation:



$$\left[-\overset{H}{\underset{H}{C}}-\overset{COOH}{\underset{CH_3}{C}}-\right]_m \rightleftharpoons \left[-\overset{H}{\underset{H}{C}}-\overset{COO^-}{\underset{CH_3}{C}}-\right]_m + mH^+$$

2. Binding of cleaved proton by nitrogen heteroatom:



Mutual activation of hydrogels due to proton binding by poly-4-vinylpyridine [13].

Long-distance interactions mechanism. Pair of next reactions may explain long-distance interactions between two hydrogel specimens [8]:

$$R_1\text{-COOH} \leftrightarrow R_1\text{-COO}^- + H^+ \tag{1}$$

$$R_2\text{=NH+ } H^+ \leftrightarrow R_2\text{=NH}_2^+ \tag{2}$$

Normally reactions (1) and (2) do not break up the electric neutrality of a system, but in our case the first reaction takes place in volume of one specimen, and the other occurs in volume of sample which is placed at relatively long distance. Hydrogen ions generated in volume of the first sample are chemically bonding by neighboring specimen. In other words, polymethacrylic acid gel (reaction 1) may be considered as a donor, and the gel-2 as an acceptor of protons (reaction 2). Consequently, both gels obtain non-zero electrostatic charge (figure2), and behavior of the system now is determined by macroscopic charge distribution.

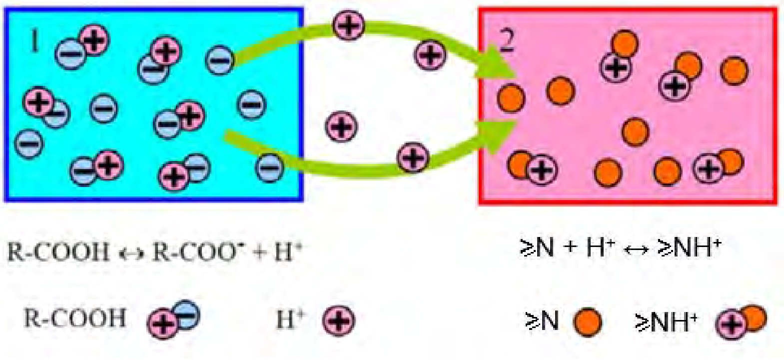


Figure 2–Formation of macroscopic charge at long-distance interaction between acceptor and donor networks [8]

First, non-zero charge of each specimen leads to repulsion of charged functional groups of each gel from each other. It is necessary to underline, that charges of functional groups inside each gel actually is moveable. Their motion has the same mechanism as holes conductivity in semiconductors. A proton may disconnect from a –COOH group and join to neighbor dissociated –COO$^-$ group. Totally, such process may be considered as motion of –COO$^-$ charged «particle». Repulsion of such negative particles leads to formation of a thin charged layer at surface of a specimen, which take part in long-distance interaction with acceptor of protons, while the degree of dissociation of weak carbon acid is low.

The lanthanum ions sorption by the gPMAA-gP4VP intergel system occurs by ionic and coordination mechanisms[8].

Electrochemical processes usually occur under condition of electric neutrality of a system as whole and itsmacroscopic parts separately. A set of electrochemical reactions may be quite complicated, but the deviationsfrom neutrality usually have scale determined by Debye length only, i.e. known types of chemical processescannot result in appearance of macroscopic electric charge and electric currents.

At the same time, appearance of macroscopic electric charge (as well as electric current of pronounceablemagnitude) in biological systems is a result of chemical reactions. The most important example is electricactivity of biological neuron networks.

Now we report that organic chemical reaction directly resulting in charging of a macroscopic specimen isobserved. Non-zero macroscopic charge appears during long-distance interactions between two polymer hydrogels, when one network is a cross-linked poly-acid, which generates moveable hydrogen ions, and another cationic hydrogel can take part in a chemical reaction of bonding of mentioned ions [8].

High sorption degree of polymers in intergel systems is due to the absence of counter ions at ionized groups. This is consequence of intergel interactions, result of which is mutual activation of hydrogels and uncompensated chargesformation along the polymer chain. Uncompensated charge is formed due to cleavage of proton from carboxyl groups during dissociation of acid hydrogel and binding of this ion with heteroatom of polybasis in an aqueous medium. Wherein charge density of basic hydrogels is limited by dissociation degree of acid hydrogel. Subsequently both hydrogels are ionized and do not have counter ions at major part of functional groups. Formation of ionized groups is caused by conformational changes of internode links of polymer chains due to what unfolding of macromolecular globe takes place. In this regard, the next goal of this work is to study the impact of dry initial state of polymer hydrogels of PMAA and P4VP on electrochemical and volume-gravimetric properties of gPMAA-gP4VPintergel system. Feature of ionization process in intergel systems is in absence of counter ions at ionized groups. This is consequence of intergel interactions, in result, there is an occurrence of hydrogels mutual activation and uncompensated charges formation along the polymer chain. Uncompensated charge is formed due to proton cleaving from carboxyl group during acid hydrogel dissociation and association of this ion by heteroatom of basic hydrogel in an aqueous medium. In this case charge density of basic hydrogels is limited by dissociation degree of acid hydrogel. Consequently, both hydrogels are ionized and do not have counter ions at charged links. The result is an increased sorption ability in comparison with individual hydrogels.

Polymer hydrogels usually are considered as intelligent materials, and their advancedapplications are developing in this way. In particular, different biomimetics and biomodeling applications arediscussing widely in current literature [8].

Interactions between different types of hydrogels are much less investigated that hydrogels themselves; onecan found only separate reports on this subject in current literature [9, 10]. Besides, cited articles [9,10] aredevoted to contact interactions of hydrogels. Now we report about sufficiently new phenomena, whichdemonstrate possibility of electrochemical interactions between specimens placed at quite long distance fromeach other [8]

Republic of Kazakhstan – is one of the largest regions in the world, which has significant reserves and prospects for expanding of the mineral resource base of rare and rare earth metals. Today, however, the production of rare metlas, rare earth metals and their compounds in Kazakhstan can be characterized as unstable, not corresponding to its potential. In some enterprises production of these metals decreased and suspended.

Meanwhile, in view modern and perspective requirements of science and technology development in the world demand for rare metal and rare earth products increases, and production of pure rare and rare earth metals and their compounds is highly profitable. Hence, for Republic of Kazakhstan priority direction in future – production, selection, production of pure rare and rare-earth metals and their compounds. Previous studies showed that in result of remote interaction hydrogels, which are in intergel systems, have significant changes in volume-gravimetric, sorption properties [1-3]. Hydrogels long-range effect (Jumadilov effect) may be a basis for creation of new technologies in hydrometallurgy, wastewater treatment, industrial and biological solutions, and in other areas, in which there is a necessity in selective separation, concentration and extraction of different charged particles [11].

EXPERIMENTAL PART

Equipment. Optical density measurements for the subsequent calculation of the lanthanum (III)nitrateconcentration were made using a Jenway-6305 (SC) spectrophotometer.

Materials. The studies were carried out in an lanthanum (III) nitrate hexahydrate solution. The hydrogels of polymethacrylic acid were synthesized in the presence of the cross-linking agent N,N-methylene-bis-acrylamide and the oxidation-reduction system $K_2S_2O_8$-$Na_2S_2O_3$. The poly-4-vinylpyridine hydrogel (gP4VP) was synthesized by Sigma-Aldrich (2% cross-linking agent). The synthesized hydrogels in the aqueous medium constituted the intergel pair «polymethacrylic acid hydrogel – poly-4-vinylpyridine hydrogel» (gPMAA-gP4VP).

The hydrogels swelling degrees were: α (gPMAA) = 20.65 g/g and α (gP4VP) = = 2.65 g/g.

Experiment. The experiments were carried out at room temperature. The researchof this intergel system was carried out as follows: the calculated amount of each hydrogel in dry form was placed in special polypropylene nets, the pores of which are permeable to low molecular ions and molecules, but impermeable to the dispersion of hydrogels. Then, an aliquot was taken for subsequent optical density measurements.

Methodology of lanthanum ions determination. The method for lanthanum ions determining in solution was based on the formation of a colored complex compound of the organic analytic reagent arsenazo (III) with lanthanum ions [12].

Extraction (sorption) degree (η) was calculated by the following equation:

$$\eta = \frac{C_{\text{initial}} - C_{\text{residual}}}{C_{\text{initial}}} \times 100\%$$

where C_{initial} is the initial concentration of lanthanum in solution, g/L; C_{residue} is theresidual concentration of lanthanum in solution, g/L.

Polymer chain binding degree (θ) was determined by calculations in accordance withthe following equation:

$$\theta = \frac{\nu_{\text{sorbed}}}{\nu} \times 100\%$$

where ν_{sorbed} – the quantity of polymer links with sorbed lanthanum, mol; ν – thetotal quantity of polymer links (if there are two hydrogels in solution, it is calculatedas sum of each polymer hydrogel links), mol.

The effective dynamic sorption capacity (Q) was calculated by the following equation:

$$Q = \frac{\nu_{\text{sorbed}}}{m_{\text{sorbent(s)}}}$$

where ν_{sorb} is the amount of sorbed metal, mole; $m_{\text{absorbent}}$ - the mass of the sorbent (if there are two hydrogels in solution, it is calculated as the sum of the two hydrogels masses), g**.**

RESULTS AND DISCUSSION

The study of the electrochemical, volumetric-gravimetric properties of the polymethacrylic acid hydrogel. During the interaction of polymethacrylic acid hydrogel with an aqueous medium, various changes in the electrochemical properties of water occur. Figure 3 demonstrates the dependence of the specific electrical conductivity of the aqueous solution on time in the presence of the PMAA hydrogel. The dependence curve clearly shows that the electrical conductivity values increase with time. A strong increase occurs in the first 6 hours of

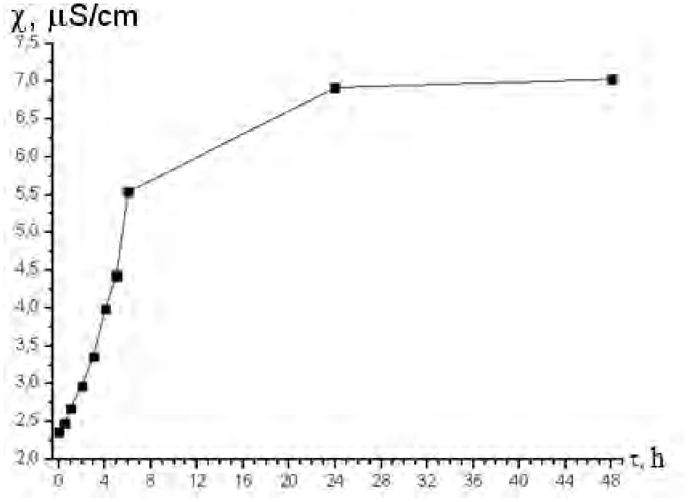


Figure 3 – Kinetics of the electrical conductivity change of the PMAA hydrogel in aqueous medium versus duration

interaction of the polymethacrylic acid hydrogel with the solution. This is facilitated by the dissociation of functional groups on the inter-node links of the macromolecule. After that, up to 48 hours, there is practically no increase in the electrical conductivity, which in turn leads to the conclusion that the system has reached a state of equilibrium.

Figure 4 shows the pHchange of PMAA hydrogel in aqueous medium versus duration.At the initial time, the pH significantly decreases in value indicating that protons released into the solution upon dissociation of the carboxyl groups.

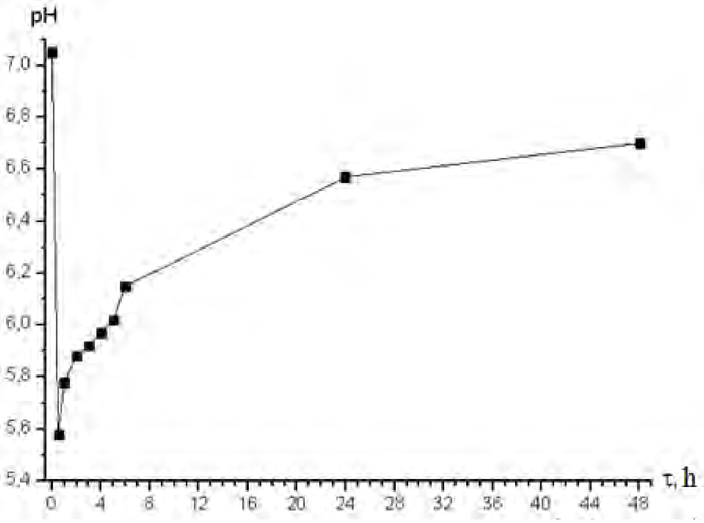


Figure 4 – Kinetics of the pH change of PMAA hydrogelin aqueous medium versus of duration

Then, there is an intensive growth of pH from 5.56 to 6.6 during 24 hours. The main reason for this phenomena is the decomposition of associates within the macromolecule, followed by the addition of protons to carboxylate-formed anions. It should be noted that in this case intramolecular associates are stronger than in the structure of polyacrylic acid. This is due to the higher degree of hydrophobicity of the polymethacrylic acid hydrogel.

Figure 5 demonstrates the dependence of the swelling coefficient of the polymethacrylic acid hydrogel. As can be seen from the figure, a sharp increase in swelling is observed during 1 hour. This is due to the functional carboxyl groups'dissociation and the unfolding of the polymer globe. Less intensive increase is observed within 6 hours. Further, the increase in the swelling coefficient occurs slowly, which allows one to conclude that equilibrium in the system is reached.

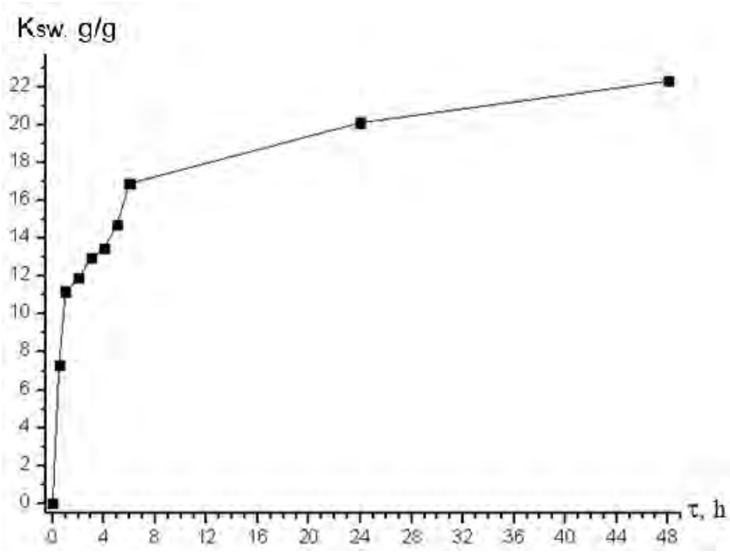


Figure 5 – Kinetics of swelling coefficient change of the PMAA hydrogel in aqueous medium versus of duration

The study of the electrochemical and volumetric-gravimetric properties of the poly-4-vinylpyridine hydrogel. The dependence of the specific electrical conductivity of the aqueous solution on time in the presence of poly-4-vinylpyridine hydrogel is shown in figure6. The obtained results indicate that the conductivity values decrease with time. This is due to the fact that the binding of protons by nitrogen heteroatoms of vinyl pyridine occurs, H^+formed as a result of the process of water molecules dissociation. As can be seen from the figure, a significant reduction occurs within 6 hours after the initiation of the poly base interaction with the aqueous solution. Then, there is a slight decrease in electrical conductivity up to 48 hours.

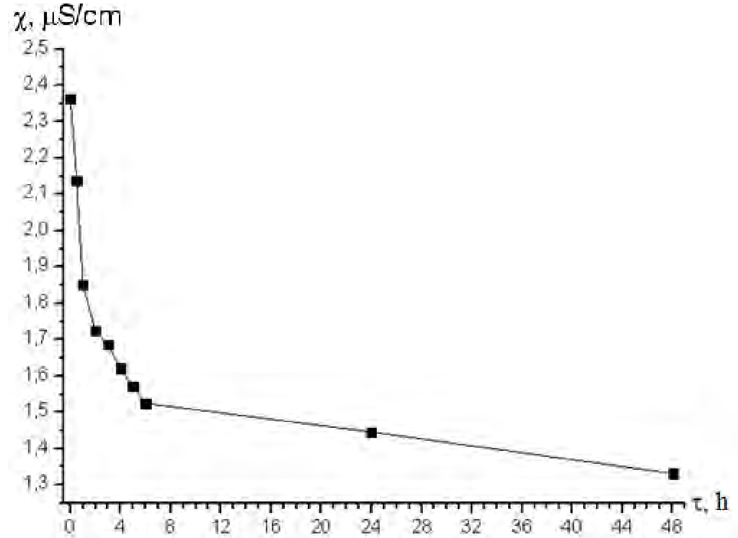


Figure 6 – Kinetics of swelling coefficient change of the P4VP hydrogel in aqueous medium versus of duration

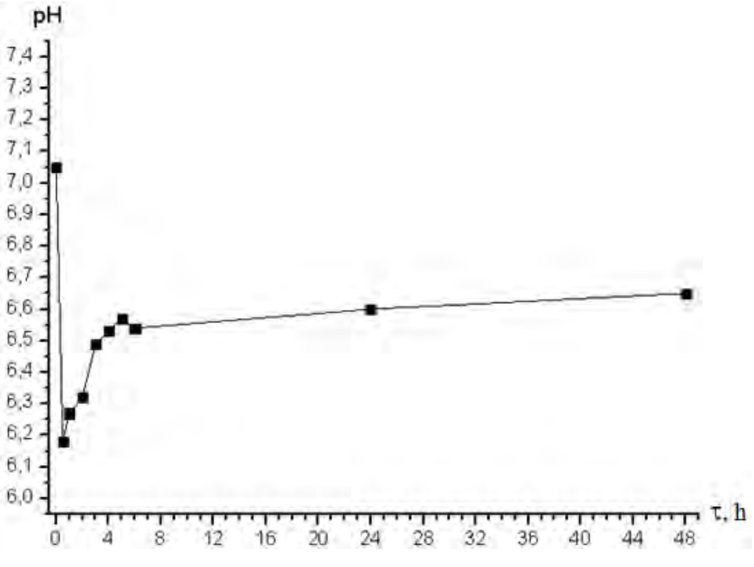


Figure 7 – Kinetics of pH change in the presence of P4VP hydrogel

Figure 7 shows the dependence of the hydrogen ion concentration on time. As can be seen from the figure, at the initial moment of time, a gradual increase in the proton concentration occurs, then their content in the solution decreases, indicating that the proton is associated with a polybase. At the initial instant of time, the polybase, as evidenced by the high values of their concentration, weakly binds the protons. Then, after 6 hours, the degree of their association increases, and the concentration of hydrogen ions in the solution decreases. This leads to an increase in the pH of the medium.

Swelling of poly-4-vinylpyridine hydrogel occurs rather intensively during 1 hour, then swelling decreases. The main reason for the decrease in swelling can be the folding of the macromolecule polymer globe. This is due to the intra-molecular cross-links formation, such as

$$\geq N \ldots H + \ldots N\equiv .$$

As can be seen from figure8, after 24 hours the swelling coefficient remains practically unchanged. In other words, we can say that the state of equilibrium is reached.

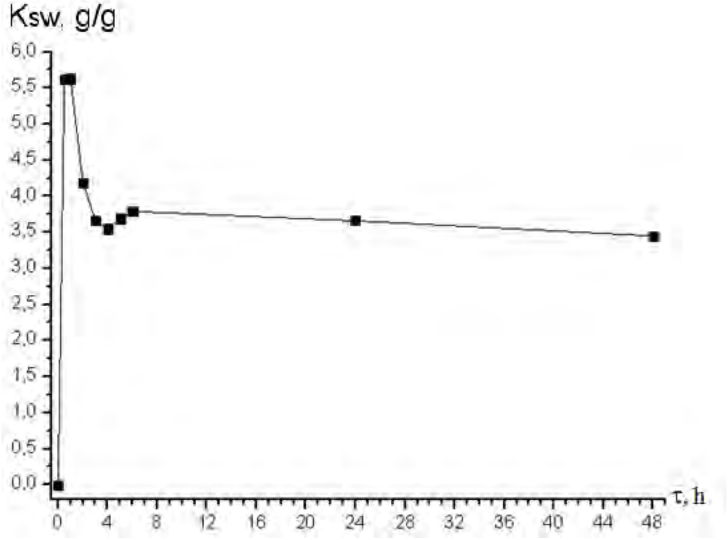


Figure 8 – Kinetics of theP4VP hydrogel swelling ratio change

Mutual activation of hydrogels in the intergel system of polymethacrylic acid hydrogel - poly-4-vinylpyridine hydrogel. In the process of remote interaction of hydrogels in the gPMAA-gP4VP intergel system, the specific electric conductivity of aqueous solutions changes. The dependence of the specific electrical conductivity on the molar ratio of hydrogels in time is shown in figure 9. As can be seen from the graph, the increase in electrical conductivity occurs at a ratio of gPMAA:gP4VP = 3:3 over the entire time of the remote interaction. The maximum electrical conductivity reached after 48 hours. The minimum values of the electrical conductivity are noted in the region of presence of only the polybase (gPMAA:gP4VP ratio=0:6), which is due to its weak dissociation.

The dependence of the hydrogen ions concentration is presented in figure 10. As can be seen from the figure, the increase in the concentration of hydrogen ions occurs at a ratio of gPMAA:gP4VP = 3:3. If we compare these data with the data

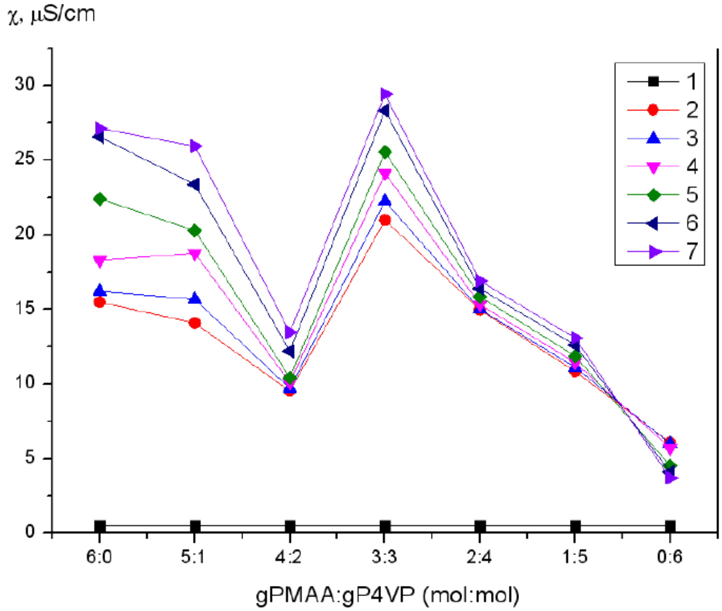


Figure 9 – Dependence on the specific electrical conductivity of aqueous solutions versus the mole content of hydrogels at various duration.
Description of curves: 1 – 0 h; 2 – 1 h; 3 – 3 h; 4 – 6 h; 5 – 24 h; 6 – 48 h

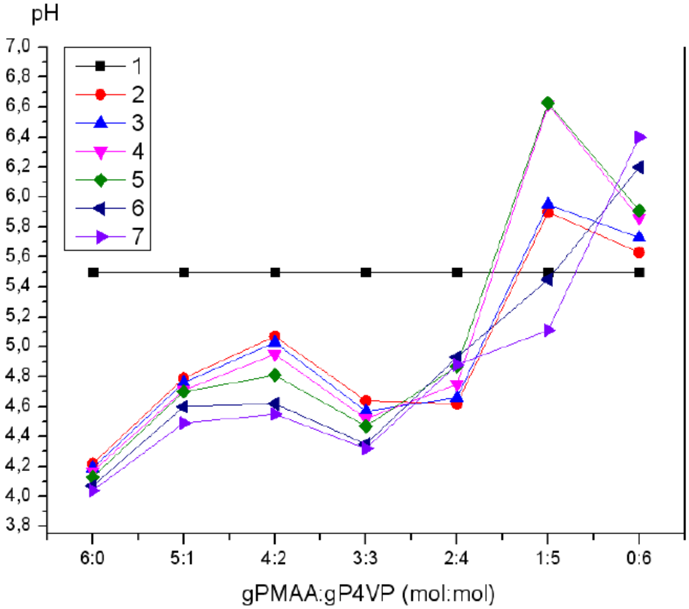


Figure 10 – pH dependence of aqueous solutions versus the mole content of hydrogels at various duration.
Description of curves: 1 – 0 h; 2 – 0.5h; 3 – 1h; 4 – 2h; 5 – 6h; 6 – 24h; 7 – 48 h

on the electrical conductivity, then we can conclude that at this ratio the process of carboxyl groups dissociation predominates over the process of attaching protons with vinylpyridine.

A significant decrease in the concentration of H^+ ions occurs at a ratio of gPMAA:gP4VP = 1:5. In the case of specific electric conductivity, at the same ratio, it is clear that the electrical conductivity values are low. The result of this is the formation of the same charged functional groups without counterions. And as a consequence - the transition of acid and basic hydrogels into a highly ionized state.

Figure 11 shows the dependence of the swelling coefficient of the acid hydrogel polymethacrylic acid on the molar ratio of hydrogels in the gPMAA:gP4VP intergel system over time. The increase in the swelling coefficient of the polyacid occurs gradually with time increasing. Moreover, it should be noted that the increase in K_H occurs with an increase in the concentration of the poly base in the solution. The minimum swelling occurs in the presence of only the polyacid in the solution (ratio gPMAA:gP4VP=6:0). The maximum swelling of the polymethacrylic acid hydrogel occurs at a ratio of gPMAA:gP4VP = 1:5 after 48 hours of remote interaction of the hydrogels. This is due to the predominance of the proton association process over the dissociation of carboxyl groups. The result of this is the transition of the acid hydrogel into a highly ionized state.

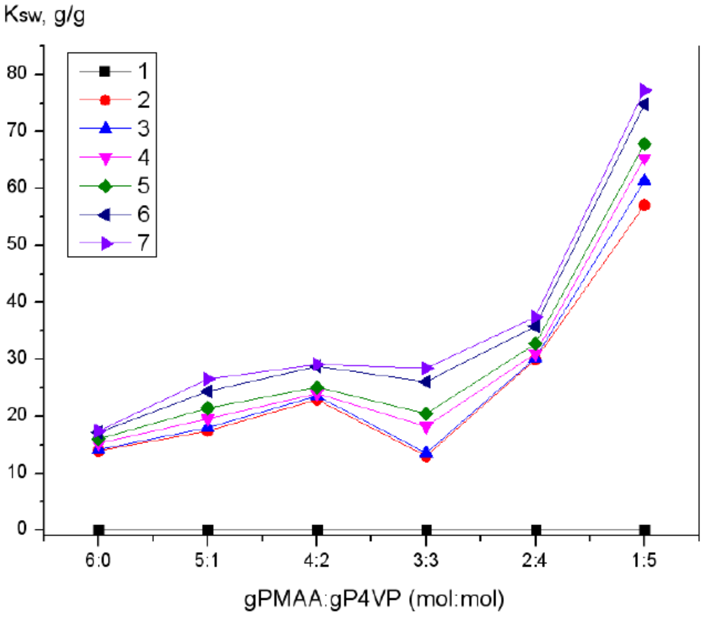


Figure 11 – Dependence of the gPMAA swelling ratio in the presence of gP4VP on the molar content of hydrogels at various duration.
Description of curves: 1 – 0 h; 2 – 1 h; 3 – 3 h; 4 – 6 h; 5 – 24 h; 6 – 48 h

Figure 12 shows the dependence of the swelling coefficient of the main hydrogel poly-4-vinylpyridine on the mole ratio of hydrogels in the gPMAA:gP4VP intergel system over time.

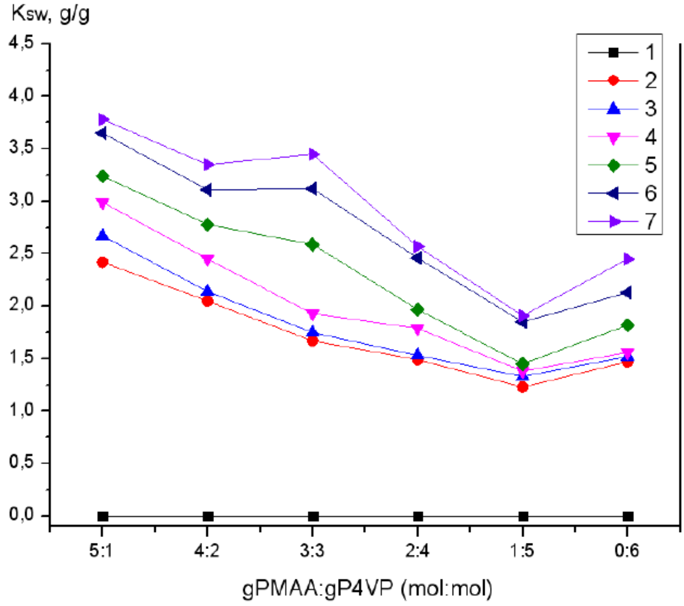


Figure 12 – Dependence of the gP4VP swelling ratio in the presence of gPMAA on the molar content of hydrogels at various duration.
Description of curves: 1 – 0 h; 2 – 1 h; 3 – 3 h; 4 – 6 h; 5 – 24 h; 6 – 48 h

As the percentage of poly-acid increases, the swelling coefficient of the poly-base increases. The minimum swelling of the poly-base occurs at a ratio of gPMAA:gP4VP = 1:5. This is due to the formation of intramolecular cross-links ≥N ... H + ... N≡, which results in folding of the polymer globeand a decrease in swelling. The maximum swelling area is the ratio of gPMAA:gP4VP= 5:1, with K_H taking the maximum values at this ratio after 48 hours.

Study of mutual activation of hydrogels gPMAA and gP4VP in intergel system. In presence of intergel system in an aqueous medium, there is an occurrence of various processes, which influence the ionic equilibrium in solution. Such processes are:

1. Dissociation of $–COOH^{–}$ groups of internode links:

$$–COOH \rightarrow COO^{–}\cdots H^{+} \rightarrow –COO^{–} + H^{+}$$

It should be noted that dissociation occurs stepwise: firstly, there is ionization with ionic pairs formation, after that ionic pairs partially dissociate on separate ions.

2. Ionization and partial dissociation of nitrogen heteroatom in pyridine ring:

$$\equiv N + H_2O \rightarrow \equiv NH^{+} \ldots OH^{–} \rightarrow \equiv NH^{+} + OH^{–}$$

3. Interaction of nitrogen heteroatom with proton, which was cleaved from carboxyl group:

$$\equiv N + H^+ \rightarrow \equiv NH^+$$

4. Formation of water molecules by interaction of H^+ and OH^- ions, which were formed in result of reaction of functional groups with water molecules:

$$H^+ + OH^- \rightarrow H_2O$$

Lanthanum ions extraction by the gPMAA-gP4VP intergel system. The dependence of lanthanum ions extraction degree by the gPMAA-gP4VP intergel system on the mole ratio of hydrogels in time is shown in figure 13. The maximum amount of lanthanum ions was extracted by the gPMAA-gP4VP intergel system at the ratio of hydrogels 4:2 (67%gMPAA-33%gP4VP). The degree of lanthanum ions extraction after 24 hours at this ratios was 90%. The obtained results indicate that the degree of lanthanum ions extraction by individual hydrogels of polymethacrylic acid and poly-4-vinylpyridine is low, the extraction rates were71% and 59%, respectively. The remaining ratios of the intergel pair in the gPMAA-gP4VP intergel system also have much higher lanthanum ion extraction rates compared to the lanthanum ions extraction of the PMAA and P4VP individual hydrogels.

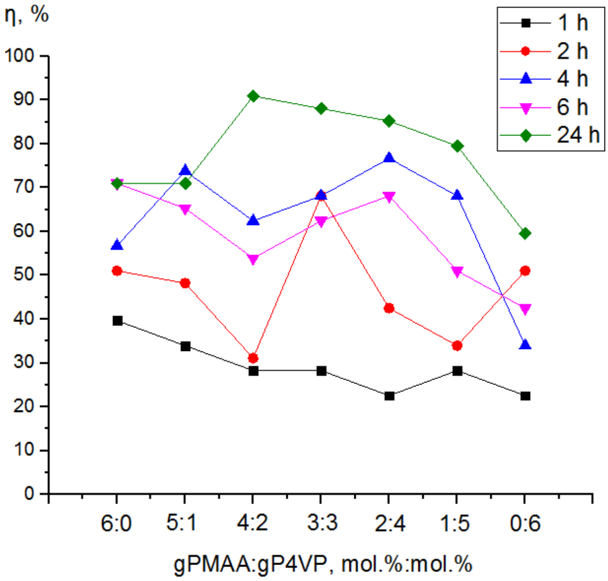


Figure 13 – The dependence of the lantanum ions extraction degree
by the gPMAA-gP4VP intergel system on the mole ratio of hydrogels in time

Figure 14 shows the dependence of thepolymer chain binding degree in relation to lanthanum ions) of the gPMAA-gP4VP intergel system in time. The maximum value of the polymer chain binding degree in the intergel system after 24 hours was 1.52% at ratio of gPMAA-gP4VP 4:2. The polymer chain binding

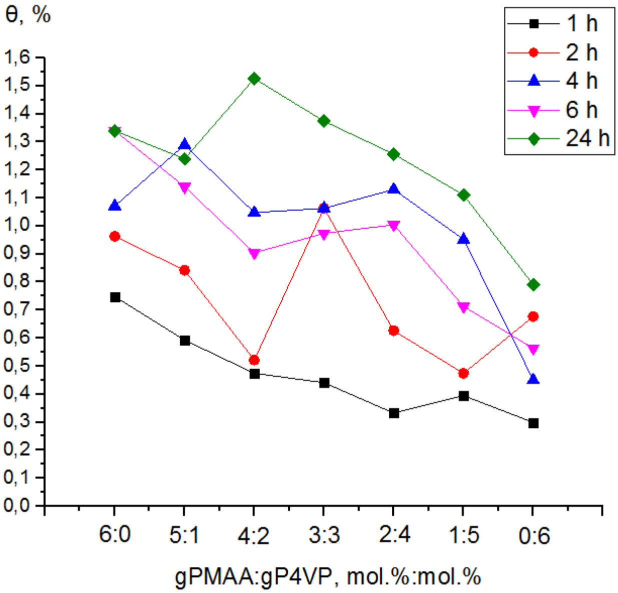


Figure 14 – The dependence of the polymer chain binding degreeof
the gPMAA-gP4VP intergel system on time in the lanthanum (III) nitrate hexahydrate medium

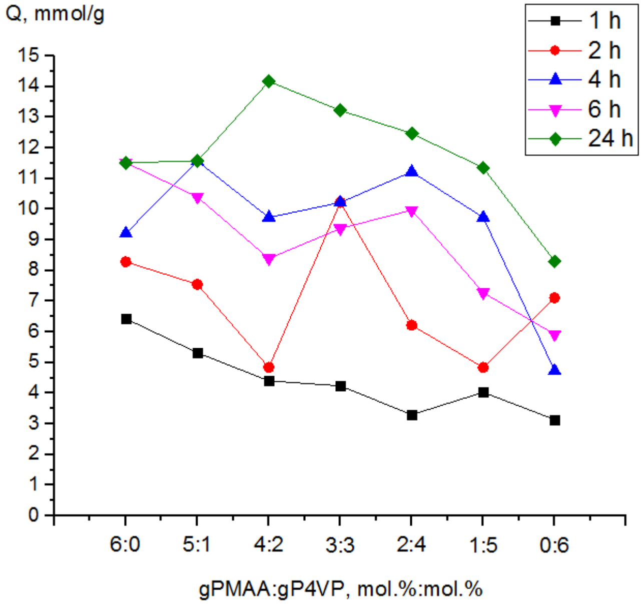


Figure 15 – The dependence of the effective dynamic exchange capacity
of the gPMAA-gP4VP intergel system on the mole ratio of hydrogels in time

degree values of polymethacrylic acid and poly-4-vinylpyridine individual hydrogels after 24 hours were1.34% and 0.79%, respectively. At 2 hours of sorption, a certain increase in the polymer chain binding degree was achieved. At 4 and 24 hours, a significant increase in the polymer chain binding degree was observed; this is particularly noticeable for 4:2 and 3:3 ratios.

Figure 15 shows the dependence of the effective dynamic exchange capacity of the gPMAA-gP4VP intergel system on the molar ratio of hydrogels in time. The obtained data indicate that the mutual activation of polymer hydrogels in the intergel pair leads to a significant increase in the values of the exchange capacity in comparison with the individual hydrogels. The maximum value of the effective dynamic exchange capacity was achieved atgPMAA-gP4VPratio of 4:2 at 24 hours of remote interaction of the hydrogels. Further remote interaction of polymer hydrogels indicates that the gPMAA-gP4VP intergel system approaches the equilibrium state which evidenced by slower growth of the effective dynamic exchange capacity as at the beginning of the remote interaction of the hydrogels.

Conclusions.

1. Individual hydrogels PMAA and P4VP do not possess sufficiently high sorption properties. The maximum degree of lanthanum ions extraction is 71% and 59% for gPMAA and gP4VP, respectively.
2. The degree of lanthanum ions extraction in the intergel system reaches the maximum values of 90% at gPMAA-gP4VP ratio of 4:2 after 24 hours.
3. Individual polymer hydrogels PMAA and P4VP have relatively low values of the polymer chain binding degree (1.34% and 0.79%, respectively) with respect to lanthanum ions due to the absence of the mutual activation phenomenon.
4. The maximum value of the polymer chain binding degreein the intergel systems is1.52% at gPMAA-gP4VP ratios of 4:2.
5. The obtained results show the possibility of creating lanthanum sorbents based on intergel systems where the conditions of activated hydrogels interaction with La^{3+} ions change.
6. Intergel systems on gPMAA-gP4VPhydrogels basis can be recommended for application in technologies of selective extraction of lanthanum ions from industrial solutions, which also may contain other ions of rare earth elements.

REFERENCES

[1] The Minor Metals Trade Association (MMTA) website https://mmta.co.uk/metals/la/

[2] The Royal Society of Chemistry website http://www.rsc.org/periodic-table/element/57/lanthanum

[3] Gupta C.K. Nagaiyar Krishnamurthy. Extractive metallurgy of rare earths. CRC Press, 2004. P. 441

[4] Alimbekova B., Erzhet B., KorganbayevaZh., Himersen H., Kaldaeva S., Kondaurov R., Jumadilov T. Electrochemical and conformational properties of intergel systems based on the cross-linkedpolyacrylic acid and vinylpyridines // Proceedings of VII international scientific-technical conference Advance in petroleum and gas industry and petrochemistry” (APGIP-7), Lviv, Ukraine, May 2014. P. 64.

[5] Alimbekova B.T., KorganbayevaZh.K., Himersen H., Kondaurov R.G., Jumadilov T.K. Features of polymethacrylic acid and poly-2-methyl-5-vinylpyridine hydrogels remote interaction in an aqueous medium // Journal of chemistry and chemical engineering. 2014. Vol. 3. P. 265-269.

[6] Jumadilov T.K., AbilovZh.A., Kaldayeva S.S., Himersen H., Kondaurov R.G. Ionic equillibrium and conformational state in intergel system based on polyacrylic acid and poly-4-vinylpyridine hydrogels // Journal of Chemical Engineering and Chemistry Research. 2014. Vol. 1. P. 253- 261.

[7] Jumadilov T.K., Abilov Zh.A., Kondaurov R.G., Khimersen H., Akhylbekova M.A. Remote interaction of hydrogels in the intergel hydrogel system of polyacrylic acid - hydrogel of poly-2-methyl-5-vinylpyridine // Chemical Journal of Kazakhstan. 2015. N 2. P. 79-84 (in Rus.).

[8] Jumadilov T., Yermukhambetova B., Panchenko S., Suleimenov I. (2012). Long-distance Electrochemical Interactions and Anomalous Ion Exchange Phenomenon. AASRI Procedia, 3, 553–558. doi:10.1016/j.aasri.2012.11.087

[9] Kokufuta E., Ogawa K., Miyake M. Polyelectrolyte complex formation between anionic and cationic nanogels in salt-free aqueous solution // Abstr. 6th Int. Symp. “Polyelectrolytes”. Dresden, 2006.

[10] Karpushkin E.A., Kechek’yan A.S., Zezin A.B. Interpolyelectrolyte reaction between the particles of oppositely charged microgels, Polymer Science, 2006. B48, 301.

[11] Jumadilov T.K., Abilov Zh.A., Kondaurov R.G. Intergel systems inrecovery of precious and rare earth metals // International Journal Of Applied And Fundamental Research. 2015. N 1.

[12] Petrukhin O.M. Workshop on the physicochemical methods of analysis. M.: Khimiya, 1987. P. 77-80 (in Rus.).

[13] Jumadilov T., AbilovZh.,Kaldayeva S. et al. // J. Chem. Eng. Chem. Res. 2014. 4, 253.

Резюме

Т. Қ. Жұмаділов, Р. Г. Кондауров, С. А. Хакімжанов, А. М. Иманғазы

ЛАНТАН ИОНДАРЫН СОРБЦИЯЛАУ БАРЫСЫНДА ИНТЕРГЕЛЬДІ ЖҮЙЕДЕГІ ПОЛИМЕТАКРИЛ ҚЫШҚЫЛЫ ЖӘНЕ ПОЛИ-4-ВИНИЛПИРИДИН ГИДРОГЕЛДЕРІНІҢ ӨЗІН-ӨЗІ ҰЙЫМДАСТЫРУЛАРЫ

Полиметакрил қышқылы гидрогелі (ПМАҚг) – поли-4-винилпиридин гидрогелі (П4ВПг) интергелді жүйесімен лантан иондарын сорбциялау процесі зерттелді. Полиметакрил қышқылы гидрогелінің өзін-өзі ұйымдастыруына негізгі гидрогельдің құрылымы көбірек әсер ететіні анықталды. ПМАҚ және П4ВП жекелеген гидрогелдерінің лантан иондарын сорбциялау дәрежесі сәйкесінше 71 және 59% құрайды. Гидрогельдердің 4:2(67%ПАҚг-33%П4ВПг) қатынасында 90% лантан сорбцияланды. ПАҚ және П4ВП гидрогельдері полимерлік тізбек бойында байланысу дәрежесі салыстырмалы түрде төмен мәндерге ие (сәйкесінше 1,34 және 0,79%).

Түйін сөздер: интергелді жүйе, өзін-өзі ұйымдастыру, сорбция, La^{3+}иондары, гидрогельдер, полиметакрил қышқылы, поли-4-винилпиридин.

Резюме

Т. К. Джумадилов, Р. Г. Кондауров, С. А. Хакімжанов, А. М. Имангазы

ВЛИЯНИЕ ЭФФЕКТА ДАЛЬНОДЕЙСТВИЯ МЕЖДУ ГИДРОГЕЛЯМИ ПОЛИМЕТАКРИЛОВОЙ КИСЛОТЫ И ПОЛИ-4-ВИНИЛПИРИДИНА НА СОРБЦИЮ ИОНОВ ЛАНТАНА

Изучен процесс сорбции ионов лантана интергелевой системой гидрогель полиметакриловой кислоты(гПМАК) – гидрогель поли-4-винилпиридина (гП4ВП). Установлено, что значительное влияние на самоорганизацию гидрогелей ПМАК оказывает структура основного гидрогеля.Степень извлечения ионов лантана индивидуальных гидрогелей ПМАК и П4ВП составляет 71 и 59%, соответственно. При соотношении 4:2 (67%гПМАК-33%гП4ВП) извлекается до 90% лантана. Индивидуальные полимерные гидрогели ПМАК и П4ВП обладают относительно невысокими значениями степени связывания полимерной цепи (1,34 и 0,79%, соответственно).

Ключевые слова: интергелевая система, сорбция, ионы La^{3+}, гидрогели, полиметакриловая кислота, поли-4-винилпиридин.