**Research of the processes proceeding in the mineral dumps**

**of gold-platinum placers**

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**Keywords.** Chemical differentiation and integration, anthropogenic oregenesis, gold-platinum mineral phase.

**Abstract.** Chemical differentiation and integration processes of gold from the anthropogenic dumps of gold-platinum placers on the example of Isovskiy mine in the Middle Urals were considered. Sediments, formed as a result of anthropogenic lithification, were studied. There is a transformation of primary composition and formation of aggregates, cemented by secondary microcrystalline oxyhydroxide-ferrous material and a variety of new ore minerals. The new gold-platinum mineral phases, formed at anthropogenic oregenesis of gold and platinoids, were shown. X-ray diffraction, electron-microscopy and X-ray microprobe studies were carried out. Anthropogenic phase’s formation mechanisms, which can be used for gold concentration process control, were tracked.

**References**

1. Kozhevnikov M.G. Revisiting the role of chemical agents in the old mine dumps enrichment. Tr. tresta «Zolotorazvedka» [Proceedings of the trust «Goldexploration»], 1935, no. 1, pp. 7-13 (in Russ.).

2. Obruchev V.A. Gold reserves in mines dumps and possibility of technical extraction. Izvestiya AN SSSR. Ser. geol. [Proceedings of the USSR Academy of Sciences. Geology], 1942, no. 3, pp. 48-57 (in Russ.).

3. Melentyev V.A., Panteleyev V.G. Escorial gold materials and ash dumps. M.: Energiya, 1978 (in Russ.).

4. Arshanov V.C., Yevpatyevskiy P.V. Landscape geochemistry and technogenesis. M.: Nauka, 1990 (in Russ.).

5. Izbekov E.D., Kopylov R.N. Structure and metallic grade of the anthropogenic deposits in gold-bearing valleys of Yakutia. Allyuviy [Alluvium], Perm, 1992, pp. 127-135 (in Russ.).

6. Naumov V.A. Alluvial anthropogenic deposits of the Chusovoy river basin. Allyuviy [Alluvium], Perm, 1992, pp. 118-127 (in Russ.).

7. Naumov V.A. Formation and distribution features of the precious metals in Ural anthropogenic placers and dump. Gornyy zhurnal [Mining Journal]. Yekaterinburg, 1994, no. 8, pp. 39-50 (in Russ.).

8. Feklichev V.G., Gerasimenko V.Ya., Spitsyn A.N. Anthropogenic metallic iron and iron phosphosilicides of ash dump. Zapiski VMO [Proceedings of the Russian Mineralogical Society], 1999, no. 1, pp. 50-53 (in Russ.).

9. Bortnikova S.B., Gaskova O.L., Ayriyan A.A. Anthropogenic lakes: formation, development, influence on an environment. Novosibirsk: Izd-vo SO RAN «Geo», 2003 (in Russ.).

10. Komarov M.A., Aliskerov V.A., Kusevich V.I., Zavertkin V.L. Mining waste products – an additional source of mineral raw material. Mineralnyye resursy Rossii [Mineral Recourses of Russia], 2007, no. 4, pp. 3-5 (in Russ.).

11. Tselyuk D.I. Features of ash deposits mineral structure from Middle Siberia ash dump. Razvedka i okhrana nedr [Prospect and protection of mineral resources], 2010, no. 1, pp. 67-71 (in Russ.).

12. Khazov A.F. Modified and authigenous minerals in anthropogenic waste products (the case of Isovsky mine dumps). Geomaterialy dlya vysokikh tekhnologiy, almazy, blagorodnyye metally, samotsvety Timano-Uralskogo regiona: Materialy Vserossiyskogo mineralogicheskogo seminara s mezhdunarodnym uchastiyem [Geomaterials for high technologies, diamonds, precious metals, semi-precious stones of the Timan-Ural region: Papers of the All-Russia mineralogical seminar with the international participation]. Syktyvkar: Geoprint, 2010, pp. 188-193 (in Russ.).

13. Khazov A.F. Mining waste products – the important reserve of mineral resources for the future generations. Vestnik Instituta geologii Komi NTsUrO RAN [Herald of the Geologic Institute of the Komi Branch of the RAS], 2010, no. 9/2, pp. 32-33 (in Russ.).

14. Gaskova O.L., Bortnikova S.B., Ayriyants A.A. Heavy metals behaviour in the drainage unloading area of the Salagaev tailing dump (m. Salair, Kemerovsky rigion). Geokhimiya [Geochemistry], 2004, no. 1, pp. 70-81 (in Russ.).

15. Bortnikova S.B., Gaskova O.L., Bessonova Ye.P. Anthropogenic systems geochemistry. Novosibirsk: SO RAN «Geo», 2006 (in Russ.).

16. Gaskova O.L., Bukaty M.B., Shironosova G.P., Kabannik V.G. Thermodynamic model of the bivalent heavy metals occlusion by calcite in natural anthropogenic conditions. Geologiya i geofizika [Geology and geophysics], 2009, v. 50, no. 3, pp. 115-126 (in Russ.).

17. Grekhnev N.I., Zhovinskiy E.Ya. Geochemistry technogenesis of Dalnegorsk mining area of Russian South Seaside. Mineralogicheskiy zhurnal [Mineralogical journal], 2009, v. 31, no. 4, pp. 77-82 (in Russ.).

18. Silayev V.I., Khazov A.F., Piskunova N.N. Estimation of mineral deposits: chemistry, geochemistry, mineralogy. Mineralogo-tekhnologicheskaya otsenka mestorozhdeniy poleznykh iskopayemykh i problemy raskrytiya mineralov [Mineral-technological estimation of deposits of minerals and problems of disclosing of minerals]. Petrozavodsk: Karelskiy NTs RAN, 2010, pp. 35-47 (in Russ.).

19. Generalov M.Ye., Naumov V.A. Gold transformation in the Ural anthropogenic placer deposits and dumps. Uralskiy geologicheskiy zhurnal [Ural Geologic Journal], 1998, no. 4, pp. 19-56 (in Russ.).

20. Generalov M.Ye., Naumov V.A., Mokhov A.V., Trubkin N.V. Isovit (Cr,Fe)23C6 – a new mineral from Ural gold-platinum containing placer deposits. Zapiski Vserossiyskogo mineralogicheskogo obshchestva [Proceedings of the Russian Mineralogical Society], 1998, v. 127, no. 5. pp. 26-37 (in Russ.).

21. Khazov A.F. Authigene mineralogenesis as a form of gold-platinum placer deposit epigenesis and a factor of formation anthropogenic deposits. Litosfera Timano-Severouralskogo regiona [Timan-North Ural Region Lithosphere], Syktyvkar: Geoprint, 2008, pp. 106-115 (in Russ.).

22. Khazov A.F. Authigene mineralogenesis in the Isovskiy mine anthropogenic deposits. Struktura, veshchestvo, istoriya litosfery Timano-Severouralskogo segmenta: Materialy 19-y molodezhnoy nauchnoy konferentsii [Timan-North Ural Region Structure, Substance, Lithosphere history: Papers of 19-th Youth Scientific Conference], Syktyvkar, 2010, pp. 232 (in Russ.).

23. Khazov A.F., Naumov V.A. Authigene mineralogenesis in mountain mine dump of the Isovskiy gold-platinum placer deposits. Materialy I Mezhdunarodnoy nauchno-prakticheskoy konferentsii molodykh uchenykh i spetsialistov, posvyashchennoy pamyati akademika A. P. Karpinskogo [Papers of the I International scientific and practical conference of young scientists and experts, dedicated to the memory of Academician A.P. Karpinsky], SPb.: Izd-vo VSEGEI, 2009, pp. 241-244 (in Russ.).

24. Khazov A.F., Naumov V.A. Mountain mine dumps as the medium of anthropogenic ore deposits formation (the case of Isovsky mine dumps). Mineralogicheskaya interventsiya v mikro- i nanomir: Materialy Mezhdunarodnogo mineralogicheskogo seminara [Mineralogical intervention in micro- and a nano-world: Papers of the International Mineralogical Seminar], Syktyvkar: Geoprint, 2009, pp. 506-507 (in Russ.).

25. Volchenko Yu.A. Ivanov K.S., Koroteyev V.A., Ozhe T. Structural-material evolution of the Ural gold-platinum containing belt crystals at formation of Ural type chrome-platinum deposits. Litosfera [Lithosphere], 2007, no. 4, pp. 73-101 (in Russ.).

26. Pushkarev Ye.V., Anikina Ye.V., Garuti Dzh., Zakkarini F.V. Nizhny Tagil type gold-platinum mineralization in the Urals: structure, the material characteristic, genesis problems. Litosfera [Lithosphere], 2007, no. 3, pp. 28-65 (in Russ.).

27. Naumov V.A., Silayev V.I., Chaykovskiy I.I. i dr. Big Shaldinka river gold-bearing placer in the Middle Ural. Perm: Izd-vo Permskogo un-ta, 2005 (in Russ.).

28. Cilayev V.I., Khazov A.F., Chaykovskiy I.I., Filippov V.N. Big Shaldinka river “live” placer. Vestnik Instituta geologii Komi NTs UrO RAN [Herald of the Geologic Institute of the Komi Branch of the RAS], 2005, no. 9, pp. 4-9 (in Russ.).

29. Naumov V.A. The concept of deposits formation management the case of anthropogenic placer gold deposits. Yestestvennyye i tekhnicheskiye nauki [Natural and Engineering Science], 2010, no. 2, pp. 262-265 (in Russ.).

30. Naumov V.A. Minerageny, technogenesis and prospects of gold-bearing alluvium complex development. The dissertation of the doctor of geology-mineralogical sciences. Permskiy gosudarstvennyy universitet, Perm, 2010 (in Russ.).

31. Naumov V.A., Lunev B.S., Naumova O.B. Geological objects with small and fine-grained gold – the important mineral raw material sources. Yestestvennyye i tekhnicheskiye nauki [Natural and Engineering Science], 2010, no. 1, pp. 174-177 (in Russ.).

32. Naumov V.A., Lunev B.S., Naumova O.B. Complex studying and use of the Perm Region sand and gravel deposits. Perspektivy nauki [Prospects of Science], 2010, no. 3, pp. 5-9 (in Russ.).

33. Naumov V.A. Minerageny and prospects of gold-bearing alluvium complex development of Urals and Cisurals. Perm, 2011 (in Russ.).

34. Naumov V.A., Osovetsky B.M. Mercuriferous gold and amalgams in mesozoic-cenozoic rocks of the Vyatka-Kama depression. Litologiia i poleznye iskopaemye [Lithology and Mineral Resources], 2013, no. 3, pp. 256 (in Russ.).

35. Generalov M.E., Naumov V.A. Gold transformations in Ural anthropogenic placers and dumps. Ural'skij geologicheskij zhurnal [Ural Geological Journal], 1998, no. 4, pp. 19-56 (in Russ.).

**Zinc-polymer coatings obtained by electrodeposition at the cathode while the amine polyelectrolyte and electrolytic reduction of zinc**

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**Keywords**: polyelectrolytes, electrolytic deposition of metals, cathodic electrodeposition, zinc-plating.

**Abstract**. First new zinc-polymer coatings were obtained by a combination of cathodic electrodeposition of amine polyelectrolyte and electrolytic recovery of zinc. The optimum composition of the mixed electrolyte consisting of amine industrial epoxy polyelectrolyte and zinc acetate was designated. The optimal conditions for obtaining of the zinc-polymer coatings of mixed electrolyte was designated: voltage range of 150-170 V, the coating time of 120 seconds. The dependence of the electrochemical equivalent deposition of additive of the zinc electrolyte in the electrodeposition bath. The electrochemical equivalent deposition decreases by increasing the content of zinc electrolyte in the composition. It has been proved that zinc metal actually deposited on the surfaces in an amount of not less than 2.6 mass%.

**Reference**

1. Pomogajlo A.N., Rozenfeld A.N., Ufljand V.K. Metal nanoparticles in polymers. // M.: Himija. 2000.
2. Dejnega Ju. F., Ulberg Z. R. Electrochemical coatings. // M.: Himija, 1989.
3. Krylova I.A. Painting by electrodeposition on the eve of 21st century. Progress in Organic Coatings, 2001, V.42, p. 1-13.
4. Kvasnikov M.Ju., Utkina I.F., Krylova I.A., Romanova O.A., Smirnov K.N. Preparation of metal-coating mix in one process of electrodeposition of metals with cathodic electrodeposition waterborne oligomeric polyelectrolyte. Himicheskaja promyshlennost' segodnja [Chemical industry today], 2014, no. 2, pp. 51-56. (in Russ.).
5. Kvasnikov M.Ju., Utkina I.F., Krylova I.A., Romanova O.A., Smirnov K.N., Kiselev M.R., Zolotarevskij V.I. Structure and properties of metal-polymer coatings obtained by a combination of one process of electrodeposition of metals with cathodic electrodeposition waterborne oligomeric polyelectrolyte. Himicheskaja promyshlennost' segodnja [Chemical industry today], 2014, [no. 3](http://elibrary.ru/contents.asp?issueid=1250995&selid=21290907), pp. 39-46. (in Russ.).
6. Kvasnikov M.Ju., Kamedchikov A.V., Kiseljov M.R., Cejtlin G.M., Polozov T.E. New chemical resistant coatings produced by electrodeposition on the cathode. Himicheskaja promyshlennost' segodnja [Chemical industry today], 2010, no. 11. pp. 17-21. (in Russ.).

**Hydrodynamic mode operation turbulent   
for washing of gas condensate with water**

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**Keywords**: gas condensate, emulsion, pressure drop, turbulent apparatus.

**Abstract**. Results of numerical calculation and experimental study of regularities of dispergating of a two-phase stream and pressure difference in the tubular turbulent device in relation to process of a water washing of gas condensate from salts are presented. Formulas for calculation of the amount of disperse inclusions and pressure difference on the ends of the device are received. Comparison of experimental data to settlement sizes confirms possibility of use of the received formulas for performance of engineering calculations. In relation to process of a water washing of gas condensate in shop of preparation of gas and gas condensate on a field Borankol (Sea Oil Company Kazmunayteniz, Kazakhstan) is offered the geometry of the tubular turbulent device diffuser-confuser type providing a pressure drop of 0.223 bar, the formation of emulsions with droplets of the dispersed phase with a diameter of 0.8 mm, the performance of the process of about 100 m3/hr.

**References**

1. Murzabekov B.E., Shevlyakov F.B., Umergalin T.G., Zakharov V.V. Washing gas condensate salts in tubular turbulent device diffuser-confused design. Vestnik Bashkirskogo universiteta [Bulletin of Bashkir University], 2012, V. 17, no.1, рр. 36-38 (in Russ.).

2. Minsker K.S., Zakharov V.P., Berlin A.A. Plug-Flow Tubular Turbulent Reactors: A New Type of Industrial Apparatus. Theoretical Foundations of Chemical Engineering, 2001, V. 35, no. 2, рр. 162-167.

3. Zakharov V.P., Berlin A.A., Monakov Yu.B. Deberdeev R. Ya. Physico-chemical basis of fast flowing liquid-phase processes. M.: Nayka, 2008 (in Russ.).

4. Barabash V. M., Belevitskaya M. A. Mass transfer of bubbles and drops in agitators. Teoreticheskie osnovy khemicheskoy technologii [Theoretical Foundations of Chemical Engineering], 1995, V. 29, no. 4, pp. 362-372 (in Russ.).

5. Kolmogorov A.N. Energy dissipation at locally isotropic turbulence. Doklady AN SSSR [Doklady AS SSSR], 1941, V. 32, no. 1, pp. 19-22 (in Russ.).

6. Mukhametzyanov A.G., Zakharov V.P., Takhavutdinov R.G., Dyakonov G.S., Minsker K.S. The movement of multiphase flow in tubular channels of diffuser-confused design. Vestnik Bashkirskogo universiteta [Bulletin of Bashkir University], 2002, no. 1, рр. 60-62 (in Russ.).

7. Takhavutdinov R.G., Dyakonov G.S., Mukhametzyanov A.G., Zakharov V.P., Minsker K.S. Intensification of dispersion in tubular turbulent devices in the production of synthetic rubber. Chemicheskay promyshlennost [Chemical industry], 2002, no 1, pp. 22-27 (in Russ.).

8. Perry R.H., Green D.W., Maloney J.O. Chemical Engineer’s Handbook New York, McGraw: Hill Book Company, 1999.

**Investigation of hydraulic resistance of the layer bulk packing in the form of rings Moebius**

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**Keywords**: bulk ring nozzle, hydraulic resistance, specific surface area, porosity, the equivalent diameter of the channel.

**Abstract**. Logarithmic graph presents the results of a study of the hydrodynamics of the layer of bulk dry and irrigated nozzles in the form of r Mobius rings of the size 55х10х0,05, made of paper sheet, the surface of which is covered with a layer of polymeric adhesive. The geometrical characteristics of the tested nozzles aregiven. The comparative analysis of the performance of the nozzle with the most common industrial nozzle - metal Rashig rings and Mobius rings of the size 50х15х0,8 are made of metal and Mylar grid. This analysis showed that the hydraulic resistance of the tested nozzles is lower than the other elements of the nozzles shown in this paper attachments.

**References**  
1. Kagan A. M., Laptev A.G., Pushnov A.S., Farakhov M.I. Contact nozzles industrial heat and mass transfer apparatus. Kazan: Fatherland, 2013.  
2. Laptev A.G. Boundary-layer model and calculation of heat and mass transfer processes. Kazan: Publishing house of Kazansk. University, 2007.  
3. Pushnov A., Vitkovskaya R. Hydrodynamics layer bulk packing in the form of rings Mobius. ENERGETIKA [Energy], 2013, T. 59, no. 2, pp.77-82.  
4. Chizh C.V., Pushnov A.S., Berengarten M.B. Structure could be laying minicircular nozzles in column apparatus. Himicheskoe i neftegazovoe machinostroenie [Chemical, oil and gas engineering], 2014, no. 4, pp. 23-26.  
5. RF patent №631185. Structured packing for heat-mass-transfer apparatus. Pushnov A.S., Masagutov D.F., bull. no. 12, 2013.  
6. Kutepov A. M. Workshop on processes and apparatuses of chemical technology. M: msuie, 2005.  
7. Timonin A.S., Baldin B.G., Borschiv V.A., Gusev U.I. and other / under the General editorship Timonina A.S. Machines and devices of chemical enterprises: textbook for universities/ Kaluga: Noosphere, 2014.

**Production of nitrogen-enriched stream by membrane gas separation**

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**Keywords:** membrane, gas separation, air separation, nitrogen, membrane plant

**Abstract.** In the last years membrane processes obtaining the nitrogen-enriched stream are gaining a larger acceptance in industry and in the market and compete with traditional technologies such as pressure swing absorption (PSA) and cryogenic distillation. The nature and characteristics of existing membranes as well as the construction of gas separation devices are discussed. The article describes the process schemes for manufacturing of membrane nitrogen units that may be applied. The main aim of the study presented was the analysis of engineering solutions in the field of membrane air separation, which are currently in use. The results of the feasibility analysis of the effectiveness of using membrane nitrogen units for varios concentrations of nitrogen-enriched air stream is presented and discussed. The data of specific operating and capital costs for different values ​​of the concentration and productivity of nitrogen-enriched stream are calculated and analyzed.

**References**

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| 1. | Dytnerskij Ju.I., Brykov V.P., Kagramanov G.G. Membrannoe razdelenie gazov. M: Himija [Chemistry], 1991. 344 p. | |
| 2. | Kagramanov G. G., Dytnerskij Ju. I., Storozhuk I. P. Membrannoe razdelenie prirodnyh, tehnologicheskih i vybrosnyh gazov // Zhurnal VHO im D. I. Mendeleeva. [Mendeleev Chemistry Journal], 1987. V. XXXII., pp. 684-692. | |
| 3. | Baker R.W., "Future Directions of Membrane Gas Separation Technology," *Ind. Eng. Chem. Res.*, No. 41, 2002. pp. 1393-1411. | |
| 3. | | Baker R.W., "Future Directions of Membrane Gas Separation Technology," *Ind. Eng. Chem. Res.*, No. 41, 2002. pp. 1393-1411. |
| 4. | | Baker R.W. Membrane technology and application. 2nd ed. California: John Wiley & Sons, Ltd, 2004. 538 pp. |
| 5. | | Na Peng, Natalia Widjojo, Panu Sukitpaneenit, May May Teoh, G. Glenn Lipscomb. Evolution of polymeric hollow fibers as sustainable technologies: Past, // Progress in Polymer Science. 2012. No. 37. pp. 1401-1424. |
| 6. | | Robeson L.M. Correlation of separation factor versus permeability for polymeric membranes // Journal of Membrane Science. 1991. No. 62. |
| 7. | | Bernardo P., Dri oli E., Golemme G., "Membrane Gas Separation: A Review/State of the Art," *Ind. Eng. Chem. Res.*, No. 48, 2009. pp. 4638-4663. |
| 8. | | Paul D.R., Yampol'skii Y. CRC: Boca Raton // Polymeric Gas Separation. FL. Vol. 1994. |

**Energy-saving schemes for extractive distillation of benzene-cyclohexane-toluene mixture with N-methylpyrrolidone as entrainer.  Part 1. Schemes of two-outlet columns**

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**Keywords:** benzene, extractive distillation, energy saving.

**Abstract.** Extractive distillation is one of the methods for benzene recovery from reforming and vapor cracking fractions. The separation considered of benzene, cyclohexane and toluene mixture as some equivalent of crude benzene fraction by extractive distillation with N-methylpyrrolidone as the entrainer. There are three different conventional schemes of this mixture separation by extractive distillation. Each scheme consists of three two-outlet columns. The aim of the research is to identify the optimal scheme by the criterion of minimum total energy consumption in column’s boilers. The study defined the optimal operating parameters for each scheme such as the total number of trays for each column, the entrainer temperature and flow rate, the entrainer and the feed trays locations. We have determined that the lowest energy consumption (7256.2 kW) has the scheme where entrainer using in the first column and recovering in the last column.

**References**

1. Gayle A.A., Somov V.E. The processes of separation and purification of products of processing of oil and gas // SPb.: Himizdat, 2012.

2. Petlyuk F.B., Serafimov L.A. Multicomponent distillation. Theory and calculation. // M.: Himiya, 1983.

3. Patent RF № 2207896. A way for separation of the acetone-chloroform azeotropic composition mixture by extractive distillation. Timoshenko A.V., Anohina E.A., Timofeev V.S., Byull. no. 19, 2003.

4. Anohina E.A., Rudakov D.G., Timoshenko A.V. Power efficiency of extractive distillation isobutyl alcohol – isobutyl acetate mixture in depending on feed composition. Khimicheskaya Technologiya [Chemical Engineering], 2010, no. 9, pp. 549–556 (in Russ.).

5. Anohina E.A., Shleynikova E.L., Timoshenko A.V. Energy efficiency of complexes with partially coupled thermally and material flows for extractive distillation of methyl acetate - chloroform mixture depending on entrainer. Vestnik MITHT [Fine Chemical Technologies], 2013, no. 2. pp. 18–25 (in Russ.).

6. [www.uhde.biz](http://www.uhde.biz/).

7. Frolkova A.K. The separation of azeotropic mixtures. Physico-chemical principales and technological techniques. // M.: Gumanitar. izd. centr VLADOS, 2010.

8. [Ivanova L.V.](http://elibrary.ru/author_items.asp?authorid=153996), [Timoshenko A.V.](http://elibrary.ru/author_items.asp?authorid=47617), [Timofeev V.S.](http://elibrary.ru/author_items.asp?authorid=46622) Synthesis of flowsheets for extractive distillation of azeotropic mixtures. [Theoretical Foundations of Chemical Engineering](http://elibrary.ru/contents.asp?issueid=367825), 2005, no. 1, pp. 16–23.

9. [Serafimov L.A.](http://elibrary.ru/author_items.asp?authorid=46495) Thermodynamic and topological analysis of heterogeneous equilibrium diagrams of multicomponent mixtures. Russian Journal of Physical Chemistry A, 2002, no. 8, pp. 1211–1224.

10. Hiaki T., Tochigi K., Kojima, K. Measurement of Vapor-Liquid Equilibria and Determination of Azeotropic Point. Fluid Phase Equilib, 1986, no. 1, pp. 83–102.

11. Gupta S.K., Rawat B.S., Goswami A.N., et. al. Isobaric vapor-liquid equilibria of the systems: Benzene-triethylene glycol, toluene-triethylene glycol and benzene-N-methlpyrrolidone. Fluid Phase Equilib, 1989, no. 1, pp. 95–102.

12. Blanco B., Beltrán S., Cabezas J.L., Coca J. Phase equilibria of binary systems formed by hydrocarbons from petroleum fractions and the solvents N-methylpyrrolidone and N,N-dimethylformamide. 1. Isobaric vapor-liquid equilibria. J. Chem. Eng. Data, 1997, no. 5, pp. 938–942.

13. Huang X., Xia S., Ma P., Song S., Ma B. Vapor liquid equilibrium of N-formylmorpholine with toluene and xylene at 101.33 kPa. J. Chem. Eng. Data, 2008, no. 1, pp. 252–255.

14. Cholinski J., Palczewska-Tulinska M., Szafranski A., Wyrzykowska-Stankiewicz D. A new method of parameter adjustment and diagnostic checks on gamma models used in vapor-liquid equilibrium calculations. Chem. Eng. Sci., 1981, no. 1, pp. 173–181.

15. Gupta S.K., Rawat B.S. Isobaric binary and ternary vapor-liquid equilibria of N-methylpyrrolidone with water and toluene at 760 mmHg. J. Chem. Eng. Data, 1992, no. 2, pp. 139–140.

16. Arifin S. and Chein I.-L. Design and Control of an Isopropyl Alcohol Dehydration Process via Extractive Distillation Using Dimethtyl Sulfoxide as an Entrainer. Ind. Eng. Chem. Res., 2008, no. 3, pp. 790–803.

17. Wang S.-J., Huang H.-P., Yu Ch.-Ch. Plantwide design of transesterification reactive disstillation to co-generate ethyl acetate and n-butanol. Ind. Eng. Chem. Res., 2010, v. 49, pp. 750–760.

18. Emhamed A.M., Czuczai B., Rev E. and Lelkes Z. Analysis of extractive distillation with mathematical programming. Ind. Eng. Chem. Res., 2008, v. 47, pp. 9983–9995.

19. Kossack S., Kraemer K., Gani R., Marquardt W. A systematic synthesis framework for extractive distillation processes. Chem. Eng. Res. And Design, 2008, v. 86, pp. 781–792.

20. Garcia-Herreros P., Gomez J.M., Gil I.D. and Rodrigues G. Optimization of the design and operation of an extractive distillation system for the production of fuel grade ethanol using glycerol as entrainer. Ind. Eng. Chem. Res., 2011, v. 50, pp. 3977–3985.

21. Kafarov V.V., Vetohin V.N., Boyarinov A.I. Programming and numerical methods in chemistry and chemical technology. // M.: Nauka, 1972.

22. Gayle A.A., Zalishhevskiy G.D. N-Methylpyrrolidone. Obtaining, properties and use as a selective solvent. // SPb.: Himizdat, 2005.