INVESTIGATION OF THE PROPERTIES OF THE DEVELOPED COMPOSITE CHEMICAL FLOTATION REAGENTS AND THEIR APPLICATION IN THE FLOTATION PROCESS

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ABSTRACT. The paper considers the results of studying the chemical composition and physicochemical properties of ore and a number of organomineral ingredients based on local raw materials and production wastes for the development of composite flotation reagents-foaming agents. A new flotation reagent-foaming agent, conventionally designated "KHF-VS", is synthesized, similar to the Russian-made T-92. The results of physicochemical studies of the developed flotation reagents-foaming agents are presented, and on their basis effective compositions for use in the process of ore flotation have been developed. To compare the sorption properties of the developed composite flotation reagents-foaming agents of the KKhF-VS class with a traditional foaming agent - T-92, we, together with the employees of Almalyk Mining and Metallurgical Combine (AGMK), conducted tests in laboratory production conditions. According to the results of the experiments, the best indicators were obtained using the sample KHF-VS-1, the extraction of copper in the rough concentrate consisted of 91.35% with a quality of 6.74% copper.

KEYWORDS: flotation reagents, foaming agents, collectors, flotation, ore, metals, foaming, metal recovery.

INTRODUCTION. Today, on a global scale, one of the main, most important problems of the mining and metallurgical complex in the metallurgical industry today is a significant reduction in the reserves of non-ferrous metal ores in terms of the amount of basic minerals, which is one of the important tasks of processing poor, refractory, refractory ores. In this aspect, the stages of enrichment of mineral raw materials, new methods and schemes of enrichment, the development of new highly efficient flotation reagents for their complex separation are of great importance [1].

In the world, flotation reagents are used in the extraction of non-ferrous and precious metals from ores. However, today, special attention is paid to the creation of import-substituting composite chemical flotation reagents-foaming agents based on local raw materials and industrial waste. In this regard, the problem of developing an effective composition of inexpensive chemical flotation reagents-foaming agents instead of imported ones and their use in the flotation process in the metallurgical industry is one of the urgent problems.

Flotation at the present time and in the future remains the most widespread process of beneficiation of the vast majority of ores. The world volume of ore beneficiated by the flotation method is estimated at one billion tons per year [2].

The main role in the flotation process is played by flotation reagents. The success of flotation and progress in its development depend on their competent and economically feasible application [3-5].

Flotation reagents are chemical compounds that promote selective adhesion of air bubbles to mineral particles and the implementation of flotation of certain components [6-8].
A characteristic feature of the reagents used in the flotation process is the selectivity of their action in relation to different phase boundaries and, in particular, to different mineral surfaces, depending on the conditions created in the aqueous medium of the pulp. Such selectivity [9-10] is always associated with the pronounced specificity of the adsorption, adsorption-chemical, electrochemical action or chemical reaction in the volume of the liquid phase of the pulp. These processes cause a change in the conditions for wetting the surface of grains of individual minerals and, consequently, their adhesion to bubbles.

The work [11] presents the development of a method for obtaining effective composite aeroflots from alcohol production wastes, the determination of their physicochemical and flotation characteristics. The optimal parameters for the synthesis of composite reagents on a pilot plant (R-620 Selecta, Spain) have been found, and the production of effective composite collectors can be achieved by regulating hydrocarbon radicals of normal and isostructure during their synthesis.
In [12], a specific property of nanobubbles is considered - spontaneous spreading over a solid hydrophobic substrate-particle adhered to them, which is caused by a high capillary gas pressure in nanobubbles. The influence of the surface activity of flotation reagents on the shape of the curves of the spreading of bubbles is shown.
In [13], the effect of the properties of foams and foam films obtained from aqueous solutions containing ionic surfactant sodium dodecyl sulfate, gelatin and an organic liquid on the efficiency of the flotation process is presented. The preparation of the most stable foams from sodium dodecyl sulfate and gelatin in the presence of an organic phase (benzene and diesel fuel) at pH = 5–7 is shown.
In the mining and metallurgical industry, the efficiency of the concentration factories largely depends on the quality of the used flotation reagents [14]. The main flotation reagents are foaming agents T-66, T-80, T-92 (derivatives of 1,3-dioxane) and MIBK, as well as organophosphorus and sulfhydryl collectors (aeroflot, potassium and sodium salts of primary alcohol xanthates) [15-16].
However, they are all produced abroad, which increases the state's import dependence. Today, the nature, structure and composition of organomineral ingredients in the flotation of copper-molybdenum ores, as well as the dependence of non-ferrous and noble metal ores on the technological factors of the flotation process using local raw materials and production wastes, and special attention is paid to the creation of import-substituting composite chemical flotation reagents. Therefore, the development of new composite chemical blowing agents based on local raw materials and industrial waste is an urgent and timely task.
In the republic, non-ferrous metallurgy is concentrated mainly on the Angren-Almalyk mining and industrial area and the state-owned enterprise JSC Almalyk MMC, JSC Navoi MMC, where flotation reagents are used to extract non-ferrous and precious metals and certain results have been achieved.
Based on the analysis of existing works, it should be noted that the issues of creating import-substituting composite chemical flotation reagents-foaming agents based on local raw materials and industrial waste require a fundamental solution.
The aim of the study is the development of import-substituting composite chemical flotation reagents and their application in the process of flotation of non-ferrous and noble metal ores in the metallurgical industry.
The objectives of the study are to study the physicochemical properties and flotation ability of the created composite chemical flotation reagents - foaming agents for their use in the process of flotation of non-ferrous and noble metal ores in the conditions of JSC "Almalyk MMC".

RESEARCH METHODS. The work used IR-spectroscopic, X-ray phase analysis and standard methods. The foaming ability and foam stability of solutions of flotation reagents-foaming agents were determined according to GOST 23409.26-78. The main ingredients of the obtained composite chemical flotation reagent-foaming agent based on local raw materials and industrial waste for use in the process of flotation of non-ferrous and noble metal ores are: modified gossypol resin, which is a waste of oil and fat production, injection-adhesive fraction - (IAF), which is a waste of alcohol production, glycerin , obtained on the basis of wastes of fat and oil production, condensed sulfitealcohol stillage (KSSB), which is a waste of alcohol production, surface active substance (surfactant) and water.

RESULTS AND DISCUSSION. To solve this problem, we carried out laboratory studies based on local raw materials and production wastes. It should be noted that the composition of the composite chemical flotation reagent-foaming agent depends on the physicochemical properties of organomineral ingredients and the nature, type, composition and content of floated ores. Developed composite flotation reagents- blowing agents are clear liquid from yellow to light brown in color. The composition of the obtained composite flotation-blowing agents varies depending on the ratio of the added organomineral ingredients and solvents.

The data obtained indicate that the considered ratio of organomineral ingredients capable of foaming and can be used to develop a flotation reagent - a foaming agent.
Table 1 shows the physicochemical properties of the obtained composite chemical flotation reagent - foaming agent.

Table 1.
Physicochemical properties of a composite chemical flotation reagent - foaming agent

Indicator	**composite chemical flotation agent - blowing agent**
Mass fraction of dimethyldioxane,%,	-
Ether number, mg KOH / g.	30-40
Flash point in an open crucible, ° C, not lower	150-160
Pour point, ° C, not higher	30-40
Density at 20 ° C, g / cm3	1,1-1,2
Viscosity, s	67

As can be seen from Table 1, the compositional chemical flotation reagent - foaming agent in its physicochemical properties meets the requirements set for the creation of foaming agents used in the flotation concentration of ores and is not inferior to the traditional expensive imported foaming agents T-92. Therefore, the frother developed by us was transferred to Almalyk MMC for pilot testing in the process of flotation concentration of non-ferrous and noble metal ores in the conditions of Almalyk MMC.
It should be noted that the composition of the composite chemical flotation reagent-foaming agent depends on the nature, type, composition, sorption and physicochemical properties of organomineral ingredients and on the content of floated ores. Therefore, in order to develop effective compositions of composite chemical flotation reagents-foaming agents, the foaming ability, stability, and physicochemical properties of the developed foaming agents based on water and water-alcohol were studied.
To study the physicochemical and technological properties of the developed composite chemical flotation reagents-foaming agents on a water and water-alcohol basis, the dependence of the composition of the developed flotation reagents-foaming agents on the density and viscosity was studied in comparison with the flotation reagent T-92.
The effectiveness of the foaming agent, all other things being equal, is affected by changes in pH and temperature. This occurs through a change in the solubility of the foaming agent, the concentration and mobility of its molecules in the pulp, which leads to a change in the rate of equalization of the density of the adsorption layer on the bubbles and, thereby, to a change in their elasticity and foam strength. One-component frothers, as a rule, are more sensitive to changes in the specified flotation parameters. Therefore, the stabilization of foaming and, accordingly, the efficiency of flotation in practical conditions is achieved by using foaming agents consisting of several components.

To determine the foaming ability and foam stability, laboratory studies of the synthesized flotation reagents-foaming agents were carried out [17]. The method is based on measuring the volume of the foam (V, ml), which is formed by stirring a solution of flotation reagents-foaming agents in water or in a liquid composition.
The comparative stability of foams containing the organic phase was determined by the height of the layer of the formed foam. In this case, a stirrer with an impeller speed of 3000 rpm was used for the experiment; graduated glass, thermometer and stopwatch.
The arithmetic mean of the results of the last three determinations was taken as the final test result.
Foam with a height of 60 cm3 to 100 cm3 is formed within 15 minutes, while no intense destruction was observed in the volume.
Figure 1 shows the results of studies on the foaming ability and foam stability of synthesized water-based blowing agents.

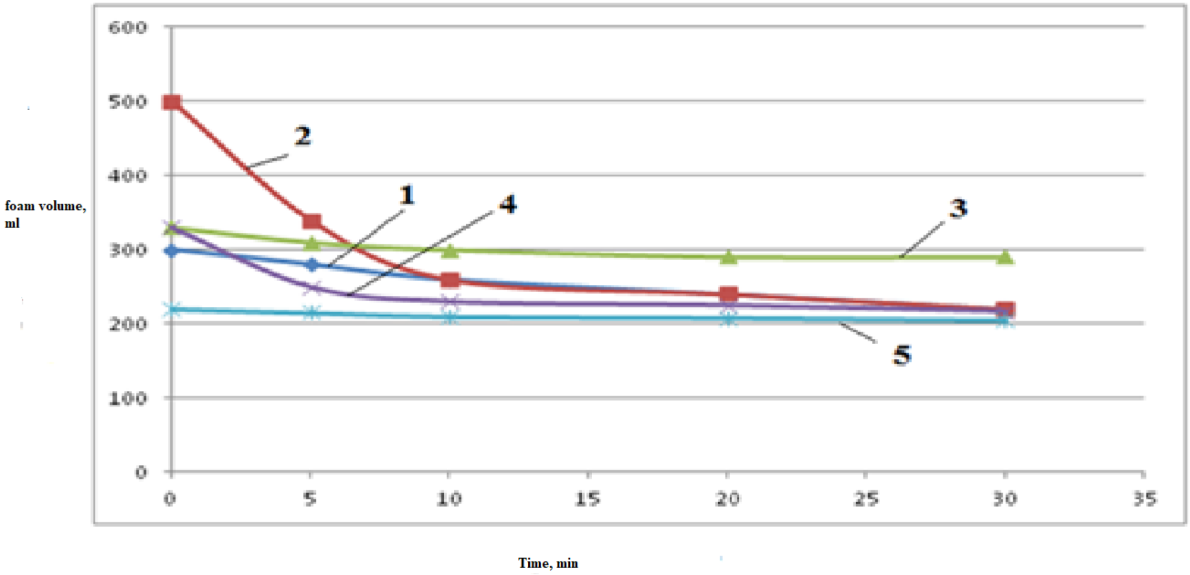

Fig. 1. Kinetics of foam stability of solutions of water-based flotation reagents-blowing agents 1-composition, 2-composition, 3-composition, 4-composition, 5-flotation agent T-92.

Figure 1 shows that the developed samples form foam of various sizes. Samples No. 1 and No. 3 gave better results in terms of foaming ability and kinetics of foam stability than samples No. 2 and No. 4.
During the flotation process, after the addition of the foaming agent, a coalescence process occurs, which slows down sharply, since as a result of adsorption at the liquid-gas interface, the foaming agent forms an oriented layer of molecules, the polar ends of which are hydrated by water dipoles. This hydrated layer increases the mechanical resistance of the casings and prevents them from fusing when they collide with each other, which allows smaller bubbles to be retained in the pulp.
Air bubbles, enclosed in a rather rigid hydration shell, close to spherical, deform little during ascent and therefore the rate of their ascent is much less than the rate of ascent of bubbles of the same size in pure water.
A decrease in the rate of rise of air bubbles under the action of foaming agents increases the air content in the pulp and, thereby, increases the number of their collisions with mineral particles. The ability of a mineral grain to gain a foothold on an air bubble depends both on the physicochemical characteristics of its surface and on the hydrodynamic regime [18-19].
Figure 2 shows the results of studies on the foaming ability and foam stability of synthesized water-alcohol-based blowing agents.

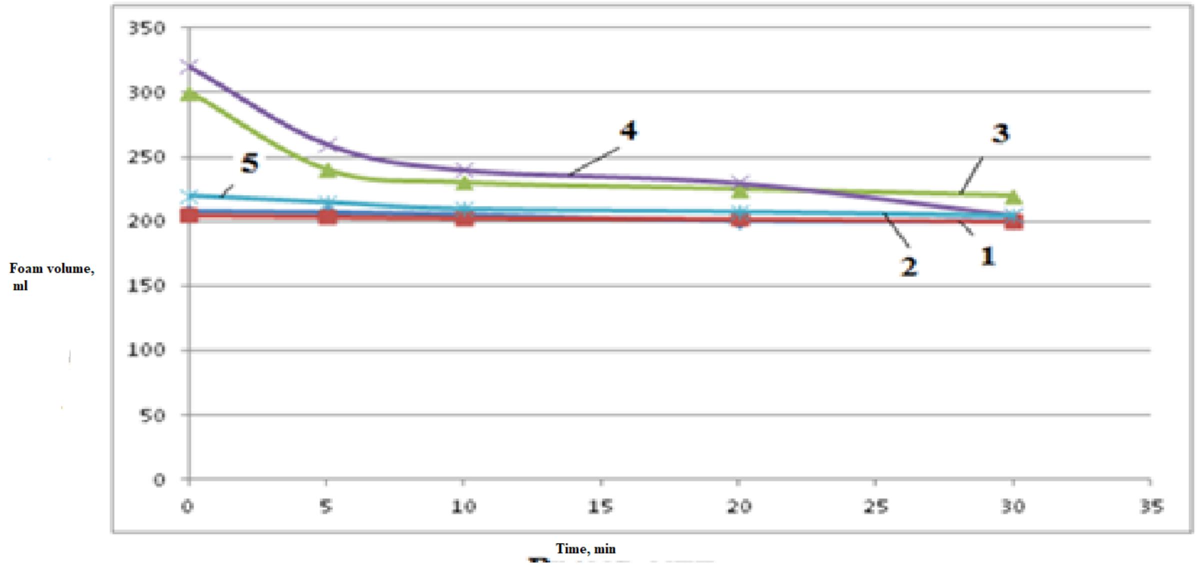

Fig. 2. Kinetics of foam stability of solutions of flotation reagents-foaming agents on a water-alcohol basis

1- 5 composition, 2- 6 composition, 3- 7 composition, 4- 8 composition, 5-Flotoreagent T-92.

From the experimental data it can be seen that the obtained composite flotation reagents-foaming agents based on alcohol waste form more foam with a size of 0.6-5 mm and they are more stable than those based on water.

The results obtained show that the main purpose of flotation reagents-foaming agents is to increase the dispersion and stabilization of air bubbles in the pulp and to increase the stability of the foam with saturated particles of the floating mineral. The study found that the size of the bubbles and the stability of the foam should be within 0.6-1.2 mm and 15 minutes, respectively.

The developed composite chemical flotation reagents-foaming agents were investigated for their serviceability, for the extraction of non-ferrous metals by the flotation method of beneficiation in laboratory-production conditions at JSC "Almalyk MMC" as an alternative to the reagent T-92.

For laboratory and production studies, a sample of the current copper-molybdenum ore from the Kalmakyr deposit was used. The chemical composition and phase analysis of this sample are shown in Tables 2, 3.

Table 2.
Chemical composition of the ore

Sample name	**Cu**	**Al_2O_3**	**MgO**	**CaO**	**SiO_2**	**$S_{общ}$**	**Fe**	**Mo**	**Au**	**Ag**
Ore 2019.	0,44	12,33	2,58	3,5	56,73	1,92	5,65	0,0068	0,84	3,16

As can be seen from the table, the ore contains small amounts of non-ferrous and noble metals that need to be concentrated.

Table - 3.
Phase composition of ore

Content of phase components				**Cu content in the sum of fractions,%**	**Sulfide content,%**
Oxidized minerals		**Sulfide minerals**			
Free	**Related**	**Primary**	**Secondary**		
0,01	0,01	0,01	0,39	0,42	95,2

Experiments on all samples were carried out in an open cycle to obtain a rough concentrate. The results of the experiments performed using the experimental samples of blowing agents were compared with the standard experiment delivered with the T-92, which are shown in table 4.

Table - 4.
The results of experiments in an open circuit on the consumption of foaming agents
Constant test conditions:

grinding: 21 min. to content class - 0.071 mm 69%; i / m – 9g / t; CaO to pH 10.5-11.0.
main fl .: 5 min; kst.-17g / t;
control fl .: 7 min; kst. - 7g / t;

Product name	Output, %	Content, %	Retrieving, %	Note
		Cu	Cu	
Main concentrate	3,4	9,6	74,98	Composite chemical flotation-frother type KHF-VS 56 g / t
Control concentrate.	2,5	2,85	16,37	
Rough concentrate.	**5,9**	**6,74**	**91,35**	
Dump tailings.	94,1	0,04	8,65	
Initial ore	100	0,44	100	
Main concentrate.	4,5	8,0	82,34	Standard T-92 56 g / t
Control concentrate.	2,5	1,6	9,15	
Rough concentrate..	**7,0**	**5,71**	**91,49**	
Dump tailings..	93,0	0,04	8,51	
Initial ore	100	0,44	100	

Based on the results of the experiments, it was shown that the developed flotation reagent-blowing agent of the KHF-VS type showed the extraction of copper in the rough concentrate 91.35% at a quality of 6.74%. The obtained results of the experimental-industrial test will be confirmed with the results of laboratory-production tests.
Thus, the data obtained indicates that using the sample developed by the State Unitary Enterprise "Science and development" and the STC LLC " COMPOSITION NANOTECHNOLOGY ", in comparison with the standard flotation reagent-blowing agent T-92, at the same costs, practically equivalent indicators were obtained in terms of copper recovery and the quality of rough concentrate.

In this regard, the created composite chemical flotation reagent-blowing agent of the KHF-VS type is recommended for further use in the production of the copper-processing plant of JSC Almalyk MMC for flotation concentration of non-ferrous and noble metal ores.
Summary
1. The optimal variant of the effective composition of composite chemical flotation reagents - blowing agents for use in the process of flotation of non-ferrous and noble metal ores in metallurgical industries is shown.
2. Investigated their physicochemical and technological properties using modern physicochemical methods for flotation concentration of non-ferrous and noble metal ores.
3. Laboratory-production tests of the created composite chemical flotation reagents-blowing agents were carried out at the OOF TsLNT under the conditions of JSC "Almalyk MMC" and it was shown that the developed composite flotation reagent-frother KHF-VS-1 is not inferior in performance characteristics to the traditional T-92 frother. Consequently, the developed composite flotation reagent-foaming agent KHF-VS-1 can be successfully used in the process of ore flotation in the Copper-Concentrating Plant (MOF) under the conditions of JSC Almalyk MMC.

REFERENCES

1. Grigoriev A.A. Production of flotation reagents // Catalysis and Petrochemistry, 2001, No. 9–10. P. 53.
2. Bocharov V.A. New scientific approaches to the selection of compositions of sulfhydryl collectors, the mechanism of their action and the substantiation of the conditions for selective flotation of sulfide minerals // Gornyi informatsionno-analiticheskiy byulleten. 2013. No. 10. S. 59-66.
3. Pockmarked V.I. Creation and application of more effective reagents based on physicochemical concepts // Ore dressing. 2002. No. 1. P. 19–23.
4. Goryachev B.Ye. Features of the action of flotation forces on particles with a chemically inhomogeneous surface // Non-ferrous metals. 2002. No. 1. S. 17-25.
5. Bukhorov Sh.B., Khaidarov A.A., Khamraev S.S. Composite foaming reagents based on local production waste during flotation of copper-molybdenum ores. // Journal. Composite materials. Tashkent. 2009. No. 1. S. 57-59.
6. Melik Gaikazyan V.I., Emelyanova N.P., Glazunova Z.I. On the capillary mechanism of strengthening the particle - bubble contact during froth flotation. // Enrichment of ores. 1976. No. 1. S. 25-31.
7. A.Kh. Khursanov, S.S. Negmatov, K.S. Negmatova, M.E. Ikramova, H.Yu. Rakhimov, D.N. Raupova, M.T. Anvarova, D.F. Ganieva. Development and creation of new water-based flotation reagents-blowing agents from local and secondary raw materials for use in the process of flotation of non-ferrous and noble metal ores // Composite materials, 2020, No. 3, p. 184-187.
8. Fedoseeva S.O., Morozov O.A. Influence of surface activity and foaming ability of heteropolar reagents on their flotation properties // Chemistry and Chemical Technology. 2018. No. 2. S. 270-279.
9. Ryaboy V.I., Asonchik K.M., Polkin V.N. and others. The use of selective collectors in the flotation of copper-zinc ores. // Processing of ores. 2008. No. 3. S. 20-21.
10. Abramov A.A., Avdokhin V.M., Morozov V.V. Automatic control of reagent modes of selective flotation of polymetallic ores // Non-ferrous metals. 1990. No. 9. S. 12-17.
11. Kenzhaliev B.K., Tusupbaev N.K., Medyanik N.L., Semushkina L.V. Study of physicochemical and flotation characteristics of composite flotation reagents // Development of useful minerals. 2019, vol. 17, no. 3, p. 4-11. https://doi.org/10.18503/1995-2732-2019-17-3-4-11.
12. V.I. Melik-Gaikazyan, V.S. Titov, N.P. Emelyanova, D.V. Dolzhenkov. Influence of capillary pressure in nanobubbles on their adhesion to particles during froth flotation. // Izvestiya vuzov. Non-ferrous metallurgy 4 2016. DOI: dx.doi.org/10.17073/0021-3438-2016-4-4-12
13. N.G. Vilkov. Influence of properties of foams and foam films on flotation separation of organic liquid // Natural sciences, Chemistry, No. 2, (14), 2016 DOI: 10.21685 / 2307-9150-2016-2-4.
14. Khursanov A.Kh., Negmatov S.S., Negmatova K.S., Ikramova M.E., Rakhimov Kh.Yu., Negmatov Zh.N. Research of new composite chemical flotation reagents - blowing agents based on local and secondary raw materials for use in the process of flotation of non-ferrous metal ores in JSC "Almalyk MMC". // Composite materials. 2020. No. 2. S. 50-54.
15. Abramov A.A. The role of sorption forms in the elementary act of flotation. // FTPRPI. - 2005.- №1. S.96-105.
16. Pockmarked V.I. The problem of using and developing new flotation reagents in Russia. // Non-ferrous metals. 2011. No. 3. S. 7-14.
17. GOST 23409.26-78. Self-hardening liquid mixtures. Method for determining the foaming ability and foam stability of solutions of surfactants.
18. Negmatov S.S., Khursanov A.Kh., Negmatova K.S., Ikramova M.E., Rakhimov Kh.Yu. Investigation of new composite chemical flotation reagents-blowing agents based on local and secondary raw materials for use in the process of flotation of non-ferrous and noble metal ores in JSC "Almalyk MMC" // Composite materials. 2020. No. 2. S. 50-54.
19. Khursanov A.Kh., Negmatov S.S., Negmatova K.S., Rakhimov Kh.Yu., Negmatov Zh.N. Development and creation of new water-based flotation reagents-foaming agents from local and secondary raw materials for use in the process of flotation of non-ferrous and noble metal ores // Composite materials. 2020.No. 3, pp. 184-187.