ISNN 3030-3907

2026/4
VOLUME 8

DEVELOPMENT OF SCIENCE

ILMIY JURNAL



Development of science

Ilmiy jurnal

2026/4 VOLUME 8

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

BOSH MUHARRIR:
Temirov Alisher Hoshim o‘g‘li – texnika fanlari falsafa doktori (PhD),Dotsent.
TAHRIRIYAT KENGASH RAISI:
Fozilov Sadriddin Fayzullayevich – texnika fanlari doktori, professor
TAHRIRIYAT KENGASH A’ZOLARI

TEXNIKA FANLARI/ TECHNICAL SCIENCES/ ТЕХНИЧЕСКИЕ НАУКИ

Bozorov G‘ayrat Rashidovich
Buxoro Davlat Texnika Universiteti, professor
Abdurahmonov Olim Rustamovich
Buxoro Davlat Texnika Universiteti, professor
Adizov Bobur Zamirovich
O‘zbekiston Respublikasi Fanlar akademiyasi Umumiy va noorganik kimyo instituti, professor
Hayitov Ruslan Rustamjonovich
Buxoro Davlat Texnika Universiteti, professor
Jumayev Qayum Karimovich
Buxoro Davlat Texnika Universiteti, professor.
Berdiyev Dorob Murodovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor
Maxmudov Rafiq Amonovich
Buxoro Davlat Texnika Universiteti, professor.
Tilloyev Lochin Ismatilloyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Raxmonov Qahramon Sanakulovich
Buxoro Davlat Texnika Universiteti, dotsent.
Barakayev Nusratullo Rajabovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor.
Jo‘rayev Xayrullo Fayziyevich
Buxoro Davlat Texnika Universiteti, professor.
Panoyev Erali Rajabboyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Ataullayev Sherzod Nabiullyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Malik Negmurodovich
Buxoro Davlat Texnika Universiteti, dotsent.
Axmedova Ozoda Bahronovna
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti.
Safarov Bahri Jumayevich
Buxoro Davlat Texnika Universiteti, dotsent.
Xaydarov Axtam Amonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Safarov Jasur Alijon o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Асадова Раъно Дилмуратовна
Тошкент Давлат техника университети доценти

KIMYO FANLARI/ CHEMICAL SCIENCES/ ХИМИЧЕСКИЕ НАУКИ

Axmedov Voxid Nizomovich
Buxoro Davlat Texnika Universiteti, professor
Umarov Baqo Bafoyevich
Buxoro Davlat Universiteti, professor
Kodirov Abduaxad Abduraximovich
Qarshi davlat Universiteti, professor
Qurbonov Mingniqul Jumagulovich
Qarshi davlat Universiteti, dotsent
Turemuratov Sharibay Naurizbaevich
O‘zbekiston Respublikasi Fanlar akademiyasi Qoraqalpog‘iston bo‘limi Bosh ilmiy kotibi, professor
Tursunov Kaxor Shonazarovich
Qarshi davlat Universiteti, professor
Do‘stov Hamro
Buxoro Davlat Texnika Universiteti, professor
Panoyev Nodir Shavkatovich
Buxoro Davlat Texnika Universiteti, dotsent.
Olimov Bobur Bahodir o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Kasimov Sherzod Abduazimovich
Termiz Davlat Universiteti, professor.
Aliqulov Rustam Valiyevich
Termiz Davlat Universiteti, professor
Tropov Xamza Tursunovich
Samarqand Davlat Universiteti, professor

IQTISODIYOT FANLARI/ ECONOMICS/ ЭКОНОМИЧЕСКИЕ НАУКИ

Nizamov Aslitdin Badreddinovich
Buxoro Davlat Texnika Universiteti, professor.
Boboyev Akmal Choriyevich
Buxoro Davlat Texnika Universiteti, professor.
Ergashxojayeva Shaxnoza Djasurovna
Toshkent davlat iqtisodiyot universiteti, professor
Saidaxmedova Nodira Ilxomovna
Toshkent davlat iqtisodiyot universiteti, professor
Muxsinov Bekzod Toxirovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shakarov Qulmat Ashirovich
Renessans ta'lim universiteti,dotsent.
Jumaeva Zulfiya Qayumovna
Buxoro Davlat Texnika Universiteti, dotsent.
Norova Salomat Yusupovna
Buxoro Davlat Texnika Universiteti, dotsent.
Avezova Shaxnoza Maxmudjonovna
Buxoro Davlat Texnika Universiteti, dotsent.
Jalilov Jamshid G‘anijonovich
Toshkent davlat iqtisodiyot universiteti, dotsent
Xasanova Gulruh Djumanazarovna
Buxoro Davlat Texnika Universiteti, dotsent.

PEDAGOGIKA FANLARI/ PEDAGOGICAL SCIENCES / ПЕДАГОГИЧЕСКИЕ НАУКИ

Siddiqova Sadoqat G‘afforovna
Buxoro Davlat Texnika Universiteti, dotsent.
Zoyirov Erkin Xalilovich
Buxoro Davlat Texnika Universiteti, DSc, professor
Gaffarov Feruz Hasanovich
Puchon Universiteti, *professor*
Ruziyev Davron Yuldashevich
Buxoro Davlat Universiteti, professor
Muradova Firuza Rashidovna
Buxoro Davlat Texnika Universiteti, professor.
Yunusova Gulandon Samiyevna
Buxoro Davlat Texnika Universiteti, professor.
To‘xtayeva Zebo Sharifovna
Buxoro Davlat Texnika Universiteti, professor.
Navro‘zova Gulchixra Nigmatovna
Buxoro Davlat Texnika Universiteti, dotsent.
Uzoqova Laylo Polvonovna
Buxoro muhandislik – texnologiya instituti, dotsent.
To‘raqulova Marjona Qiyom qizi
Buxoro Davlat Texnika Universiteti, dotsent.
Muradova Zarina Rashidovna
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Sanjar Aslonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shodiyev Jahongir Jo‘raqulovich
Buxoro Davlat Texnika Universiteti, dotsent
Gaffarov Laziz Hasanovich
Buxoro muhandislik – texnologiya instituti, dotsent.

Tahririyat a’zolarning to‘liq ro‘yxati jurnalning www.devos.uz saytida keltirilgan.

Tahririyat hay’ati a’zolarining tarkibini o‘zgartirish hamda qo‘shimcha kiritish yoki tahririyat a’zoligidan chiqarish bosh muharrir tomonidan amalga oshiriladi.

ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

To‘plam elektron ko‘rinishda (pdf formatida) mualliflarga taqdim etiladi. To‘plamga kiritiladigan maqolalarning mazmuni, ulardagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligiga hamda har qanday fikr - mulohazalarga mualliflarning o‘zlari mas’ul hisoblanadilar. Talablarga javob bermaydigan maqolalar to‘plamga kiritilmaydi. Tashkiliy qo‘mita maqola matnini qisqartirish, qisman tuzatish kiritish, seksiyalarga joylashtirish huquqiga ega.

ISSN 3030-3907

COMPREHENSIVE PROCESSING OF COPPER FROM COPPER CONCENTRATION PLANT TAILINGS USING ROASTING

Mirzajanova S.B.
Associate Professor, Department of Metallurgy, Tashkent State Technical University.
ORCID: 0000-0002-0375-6415
Matkarimov S.T.
Doctor of Technical Sciences, Professor Department of Metallurgy, Tashkent State Technical University, ORCID: 0000-0003-2393-6576
Rakhimov Kh.Sh.
Leading Researcher, Laboratory of Materials Science, Center for Innovative Technology Research, National Academy of Sciences of Tajikistan. ORCID: 0009-0009-6246-2917
Saydirakhimova M.I.
PhD Student, Department of Metallurgy, Tashkent State Technical University. ORCID: 0009-0003-4535-9949

Abstract. The article notes that with the development of modern technologies, the amount of waste generated in the metallurgical industry increases annually. One of the most effective ways to address the problem of industrial waste is the development and implementation of waste-free technologies. The research involved grinding, magnetic separation, and thermochemical treatment using lime. The optimal lime ratio was 1:1, which increased the copper content from 0.08% to 0.13%, zinc from 0.028% to 0.055%, and reduced the iron content from 6.37% to 4.18%. The results confirm the effectiveness of lime as a reagent for reducing iron silicate content and increasing copper and zinc recovery from flotation tailings. This study has practical implications for optimizing industrial metallurgical waste recycling processes and improving the environmental performance of production.

Keywords. waste heaps, copper processing plant waste, flotation, slag, roasting, minerals, environment, metallurgical units, muffle furnace.

Аннотация. В статье отмечается, что с развитием современных технологий объем отходов, образующихся в металлургической промышленности, ежегодно увеличивается. Одним из наиболее эффективных способов решения проблемы промышленных отходов является разработка и внедрение безотходных технологий. Исследование включало измельчение, магнитную сепарацию и термохимическую обработку с использованием извести. Оптимальное соотношение извести составило 1:1, что увеличило содержание меди с 0,08% до 0,13%, цинка с 0,028% до 0,055% и снизило содержание железа с 6,37% до 4,18%. Результаты подтверждают эффективность извести

ISSN 3030-3907

как реагента для снижения содержания силиката железа и повышения извлечения меди и цинка из отходов флотации. Данное исследование имеет практическое значение для оптимизации процессов переработки промышленных металлургических отходов и повышения экологической эффективности производства.

Ключевые слова: отвалы отходов, отходы медеперерабатывающих заводов, флотация, шлак, обжиг, минералы, окружающая среда, металлургические установки, муфельная печь.

Annotatsiya. Ushbu maqolada zamonaviy texnologiyalarning rivojlanishi bilan metallurgiya sanoatida hosil bo‘ladigan chiqindilar hajmi har yili ortib borayotgani ta'kidlangan. Sanoat chiqindilari muammosini hal qilishning eng samarali usullaridan biri chiqindisiz texnologiyalarni ishlab chiqish va joriy etishdir. Tadqiqot ohak yordamida maydalash, magnit ajratish va termokimyoviy ishlov berishni o‘z ichiga olgan. Optimal ohak nisbati 1:1 ni tashkil etdi, bu mis miqdorini 0,08% dan 0,13% gacha, ruxni 0,028% dan 0,055% gacha oshirdi va temir miqdorini 6,37% dan 4,18% gacha kamaytirdi. Natijalar ohakning temir silikat miqdorini kamaytirish va flotatsiya chiqindilaridan mis va ruxni qayta tiklashni oshirish uchun reagent sifatida samaradorligini tasdiqlaydi. Ushbu tadqiqot sanoat metallurgiya chiqindilarini qayta ishlash jarayonlarini optimallashtirish va ishlab chiqarishning ekologik samaradorligini oshirish uchun amaliy ahamiyatga ega.

Kalit so‘zlar; chiqindilar axlatxonalari, misni qayta ishlash zavodi chiqindilari, flotatsiya, shlak, qovurish, minerallar, atrof-muhit, metallurgiya zavodlari, mufle pechi.

INTRODUCTION.

The non-ferrous metallurgy industry encompasses the mining, beneficiation, and processing of ferrous and non-ferrous metal ores, as well as the production of finished products. A key player in this industry is the Almalyk Mining and Metallurgical Plant (AMMP), the flagship of Uzbekistan's non-ferrous metallurgy industry. The plant mines and processes copper, lead-zinc, molybdenum, gold, and silver ores. Its production facilities are based at the rich deposits of Kalmakir, Angren, Chodak, Khondiza, and others. Despite high production figures – up to 148,000 tons of copper, 120,000 tons of zinc, and 930,000 tons of sulfuric acid per year—metallurgical operations generate a significant amount of industrial waste, which has a negative impact on the environment [1].

Therefore, one of the priority tasks at the current stage of the industry's development is the development and implementation of effective technologies for extracting non-ferrous metals from industrial waste, including slag and

ISSN 3030-3907

beneficiation tailings, in order to improve the comprehensive use of mineral raw materials and reduce the environmental impact.

According to available data, the leading countries in copper production are Chile, the United States, Japan, Russia, and China, with almost 60% of copper produced coming from the recycling of secondary copper raw materials. The copper content in recycled materials ranges from 0.21% to 1.68%, and it is primarily found in an oxidized form [2]. At the Kalmakir deposit, 75–80% of copper is extracted from sulfide ores, which are processed at the Altai Mining and Metallurgical Combine (AMMP), one of the country's largest enterprises. Copper ores in Uzbekistan contain: 15–20% Cu, 6% SiO_2, 30–33% Fe, 22–36% S, 0.5% CaO, and other trace metals [3].

Processing sulfide concentrates using traditional pyro metallurgical methods remains the most popular method for producing copper and other non-ferrous metals. The most commonly used pyro metallurgical process for processing sulfide copper concentrates is charge preparation (roasting is possible), smelting for matte, converting, refining of blister copper, and electrolysis [4].

The complexity of the mineral composition of sulfide polymetallic raw materials, such as copper – zinc materials with a widely varying composition (%): 1–10 copper, 6–30 zinc, 16–39 iron, 30–47 sulfur, complicates their processing.

In [5], for processing sulfide copper-zinc middlings with the following content (wt.%): Cu – 10; Zn – 23; Pb – 0.5; Fe – 21; S – 36; CaO – 0.5; SiO_2 – 2.5; Al_2O_3 – 5.5; coke (80.0% C) and limestone (94.91% CaCO3), the authors used the thermodynamic modeling method with the “HSC Chemistry 6” software. Equilibrium modeling of the copper-zinc middlings was carried out between the initial reagents and the calcination products depending on the temperature characteristic of solid-phase reactions – 1150 °C. A theoretical method for extracting zinc into the gas phase (more than 90%), iron metallization and CaS formation is presented. The solid residue after dezincification contained, %: CaS – 49; Fe_{met} – 15; C – 3.5 [6].

Traditional mining technologies do not ensure the comprehensive extraction of valuable minerals from such ores, and a significant portion ends up in waste heaps and tailings dams – up to 35% Cu, up to 40% Zn, up to 50% Pb, and up to 50% rare and precious metals. This generates significant amounts of waste and creates numerous "man-made deposits" containing valuable elements of various metals. Such deposits cannot be processed using traditional methods due to their unprofitability.

For this reason, the use of standard pyro metallurgical processes for copper extraction from raw materials generates large quantities of man-made waste.

ISSN 3030-3907

Furthermore, flotation enrichment of copper concentrates also generates significant volumes of waste.

After flotation processes, significant quantities of metals, primarily copper, remain in the waste heaps of copper processing plants. The average chemical composition of flotation waste from the Almalyk Mining and Metallurgical Plant (AMMP) is as follows: Cu – 1.05%, Fe – 41.78%, SiO_2 – 40.5%, Pb – 0.01832%, Zn – 0.02822%, Ca – 0.02925%, Na – 0.3265%, Mn – 0.03525% [7]. The tailings waste generated after copper concentrate enrichment at the Dabaoshan mines in China amounts to 480 million tons per year. Analysis of the sludge showed that it contains 31.50% pyrite minerals and 38.85–15.06% silicate and quartz minerals [8].

To date, the East Serbian Copper Processing Plant has produced 207 million tons of flotation process waste and 23 million tons of copper smelting process slag, occupying 68% of populated areas [9]. An analysis of the composition of the waste from the Dzhezkazgan Copper Processing Plant revealed the following: Cu – 0.14%, SiO_2 – 59.12%, Fe – 2.10%, Ag – 2.51%, Al_2O_3 – 11.15%, Ca – 4.84%, Mg – 2.01% [10]. The off-balance sheet ores of the Almalyk Mining and Metallurgical Plant currently amount to 140 million tons, of which 35% are oxidized ores, 46% are sulfide ores, and 19% are mixed ores. The copper content in these ores is determined to be between 0.35% and 0.23% [11].

In connection with this, in recent years, the Almalyk Mining and Metallurgical Plant has seen an increase in the amount of waste generated as a result of flotation, enrichment, and metallurgical production processes. A large amount of industrial waste has accumulated, and the amount of waste generated during the flotation process amounted to approximately 955 – 960 million tons, while the waste generated at copper smelters is estimated at 11-13 million tons. The enrichment using flotation methods mainly contains elements such as Cu, Zn, Mo, Fe, Au, Ag, as well as FeS_2, FeS, and Fe_7S_8 with a high sulfur content. One of the main problems is the amount of S 1.38 - 10.5% (depending on the granule size), SiO_2 25,2 – 45 %, and also the amount of Fe 28 – 45 %. When analyzing the copper and zinc content of the waste, the mineral content was Zn - 2.01 %, Cu – 0,891 %. The waste from the copper processing plant has varying sizes, therefore, to obtain accurate analytical results, the grinding process was carried out in ball mills. A 1000 g sample was taken, and the grinding process was carried out for 30 minutes. To properly analyze the process, copper processing plant waste was subjected to magnetic separation using the magnetite separation method, the results of which are listed in Table 2.

ISSN 3030-3907

Table 2.

Copper processing plant waste after magnetic separation

Sieve index	Tail weight	Magnetic fraction	%	Non-magnetic fraction	%
+ 0,200 mm	787,79 g	93,35 g	11,85	689,82 g	87,59
+ 0,140 mm	100,71 g	20,02 g	20,1	80,69 g	80,12
+ 0,100 mm	45,88 g	8,40 g	18,31	37,48 g	81,69
+ 0,080 mm	28,91 g	2,34 g	8,09	26,57 g	91,91
+ 0,071 mm	38,33 g	10,51 g	27,42	27,70 g	72,27
- 0,071 mm	21,65 g	11 g	50,8	10,65 g	49,19

From the obtained sample, it was found that with a particle size of -0.071 mm, 50% of the material was attracted to the magnet, while the other 50% was not. Theoretically, the higher the iron content, the greater the copper and zinc losses. The main focus of this study is on reducing iron content to increase copper and zinc content. Therefore, the next step was to analyze the processes for reducing iron and silicon dioxide content in copper processing plant waste.

It was found that the quartz content in the waste had a negative impact on the amount of wustite compounds, and to eliminate this effect, the kinetic role of lime was studied.

The optimal amount of lime added is a ratio of 1:0.5, which promotes silicon binding and the formation of $CaO \cdot SiO_2$. Optimal temperature and process time are important factors. For proper process performance at 1000°C and complete oxygen interaction, thorough mixing within the unit is necessary.

Research Objective

Before theoretically studying the properties of minerals, it is necessary to determine the laws governing them. Waste from the Almalyk Mining and Metallurgical Combine (AMMC) was analyzed as a sample, and a quantitative analysis was conducted. The results are presented in Table 1.

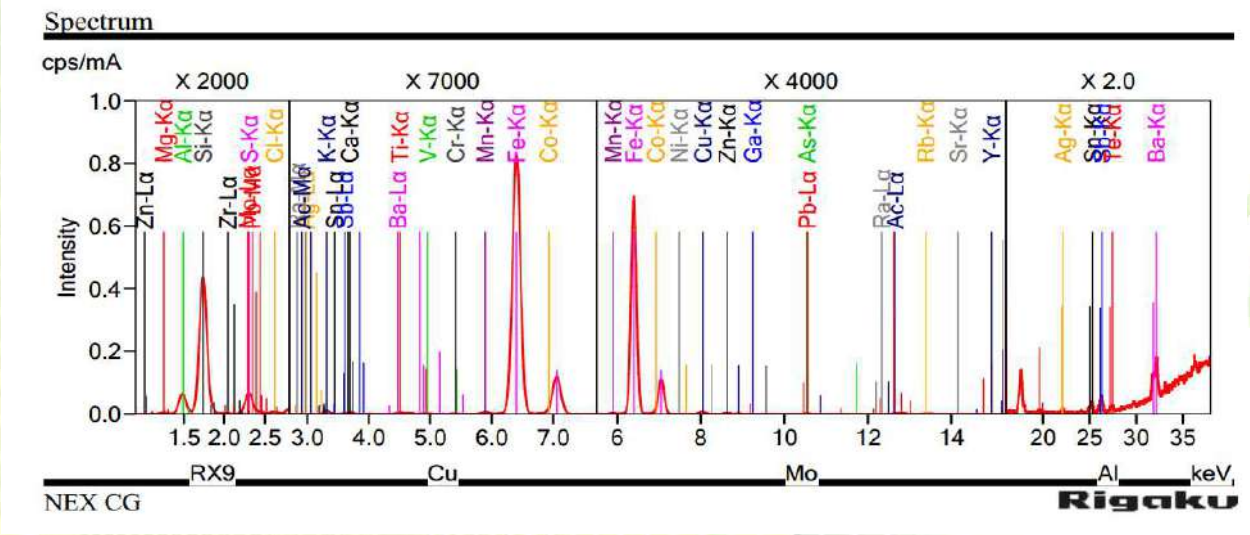
Table 1

Mineralogical and compositional composition of AMMC waste

№	Elements	In percentages, %	Elements	In percentages, %
1	Cl	0.0800	Zn	2.10
2	Na	1.99	As	0.0275
3	Mg	1.40	Rb	0.0254
4	Al	5.08	Sr	0.0372
5	Si	25.2	Y	0.0078
6	S	0.678	Zr	0.455
7	K	2.95	Mo	0.373

ISSN 3030-3907

8	Ca	4.24	Sn	0.0126
9	Ti	0.294	Sb	0.113
10	V	(0.0088)	Te	(0.0040)
11	Cr	0.0336	Ba	0.336
12	Mn	0.313	Ir	(0.0125)
13	Fe	18,20	Pb	0.535
14	Co	0.119	Ac	0.0408
15	Cu	0.891	U	(0.0026)



After determining the percentage content of the elements, their mineralogical composition was also determined to enable the correct selection of the technological process. The results are included in Table 2.

Table 2

Mineral Compounds with Oxygen

Components	Percentage	Components	Percentage
SiO_2	39,82	K_2O	0,84
Fe_2O_3	11,93	Na_2O	1,46
FeO	7,27	$S_{comm/}$	<0,4
TiO_2	1,74	S_{sulfid}	0,036
V_2O_5	0,06	SO_3	<0,01
MnO	0,14	SO_2	0,22
AI_2O_3	9,44	P_2O_5	0,13
CaO	14,84	N_2O	0,2
MgO	10,0	Others	1,874

In the next stages of the process, it is necessary to link the analyses to theoretical relationships, determine the factors that influence the formation of compounds, their interactions, and physicochemical changes, and correctly analyze

ISSN 3030-3907

the mechanism of subsequent stages [12]. To achieve this, an analysis of the mechanism and kinetics of mineral reactions is conducted. According to theoretical principles, their kinetics proceeds through the following processes:

$$2CuS = Cu_2S + 1/2S_2$$
$$2Cu_2S + 3O_2 = 2Cu_2O + SO_2$$
$$ZnS + 1{,}5O_2 = ZnO + SO_2$$
$$ZnCO_3 = ZnO + CO_2$$
$$Zn_4Si_2O_7(OH)_2 \cdot H_2O = 4ZnO + 2SiO_2 + 3H_2O$$
$$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$$
$$MgCO_3 = MgO + CO_2$$
$$2FeS_2 = 2FeS + S_2$$
$$2FeS + 3O_2 = 2FeO + 2SO_2$$
$$Fe_2O_3 + FeS = Fe_3O_4 + SO_2$$
$$3Fe_3O_4 + FeS + SiO_2 = 5Fe_2SiO_4 + SO_2$$
$$Fe_2SiO_4 + CaO = 2Fe + CaSiO_3 + SO_2$$

The presence of up to 1–1.5% sulfur in the waste, i.e., iron sulfide, prevents the extraction of Cu_2O, PbO, and ZnO compounds. The process occurs in three stages, namely: - the first stage is the removal of iron (Fe) and associated sulfur (S):

$$\mathbf{2FeS + 3O_2 = 2FeO + 2SO_2};$$

$$\Delta H_p = 2\Delta H^0{}_{FeO} + 2\Delta H^0{}_{SO} - 2\Delta H^0{}_{FeS} - 3\Delta H^0{}_{O2}$$
$$= 2 \cdot (-272{,}2) + 2 \cdot (-296{,}90) - 2 \cdot (-104{,}01)$$
$$= -930{,}18 \text{ kDj/mol.}$$

$$\Delta S_p = 2\Delta S^0{}_{FeO} + 2\Delta S^0{}_{SO2} - 2\Delta S^0{}_{FeS} - 3\Delta S^0{}_{O2}$$
$$= 2 \cdot (60{,}75) + 2 \cdot (248{,}07) - 2 \cdot (60{,}33) - 3 \cdot (205{,}03)$$
$$= -118{,}11 \text{ kDj/mol.}$$

$T_r = \Delta H_p / \Delta S = -930{,}18/-118{,}11 = 7{,}875$ K.

– второе отделить SiO_2:

$$FeSiO_3 + \mathbf{CaO} = CaSiO_3 + \mathbf{FeO};$$

$$\Delta H_p = \Delta H^0{}_{\mathbf{FeO}} + \Delta H^0{}_{CaSi} - \Delta H^0{}_{FeSi} - \Delta H^0{}_{CaO}$$
$$= (-272{,}0) + (-1635{,}1) - (-1194{,}9) - (-635{,}1)$$
$$= -77{,}1 \text{ kDj/mol.}$$

$$\Delta S_p = \Delta S^0{}_{\mathbf{FeO}} + \Delta S^0{}_{CaSiO} - \Delta S^0{}_{FeSiO3} - \Delta S^0{}_{CaO}$$
$$= 60{,}75 + 81{,}92 - 93{,}93 - 38{,}1 = 10{,}64 \text{ kDj/mol.}$$

$T_r = \Delta H_p / \Delta S = -77{,}1/10{,}64 = -7{,}246$ K

In the third stage, Fe_3O_4, with the addition of carbon (C), is converted into

ISSN 3030-3907

the following form:

$$\mathbf{Fe_3O_4 + 4CO = 3Fe + 4CO_2}$$

$$\Delta H_p = 3 \cdot \Delta H^0{}_{\mathbf{Fe}} + 4 \cdot \Delta H^0{}_{\mathrm{CO}} - \Delta H^0{}_{\mathrm{Fe3O4}} - 4 \cdot \Delta H^0{}_{\mathrm{CO}}$$
$$= 4 \cdot (-393{,}38) - (-1117{,}1) - 4 \cdot (-110{,}54)$$
$$= -14{,}26 \text{ kDj/mol.}$$

$$\Delta S_p = 3 \cdot \Delta S^0{}_{\mathbf{Fe}} + 4 \cdot \Delta S^0{}_{\mathrm{CO2}} - \Delta S^0{}_{\mathrm{Fe3O4}} - 4 \cdot \Delta S^0{}_{\mathrm{CO}}$$
$$= 3 \cdot 27{,}15 + 4 \cdot 213{,}68 - 146{,}19 - 4 \cdot 197{,}53 = -0{,}14 \text{ kDj/mol.}$$

$$T_r = \Delta H_p / \Delta S = -14{,}26/(-0{,}14) = 101{,}857 \text{ K}$$

After determining the compounds with which copper is bound, the required heat amounts and the thermodynamics of the process were calculated [13].

Analysis of the copper processing plant waste composition, the optimal granulometric composition, the thermodynamic nature of the processes, and the stoichiometric amount of reagent used, as well as a correct process calculation of the entire process, demonstrate the possibility of increasing the copper and zinc content.

A study of samples from the Kalmakir and Saricheku deposits revealed that copper is present in the minerals chalcopyrite, chalcocite, malachite, and chrysocolla, with chalcopyrite predominating. Among zinc minerals, sphalerite, smithsonite, hydrozincite, and willemite predominate; high zinc content, in particular, was found in the mineral sphalerite.

The number of samples obtained depends on the content of the substances and their mineralogical composition. A detailed compositional study is necessary for a proper process analysis. For this purpose, three samples were prepared:

— the first sample was added with lime in a ratio of 1:1,

— the second with lime in a ratio of 1:0.5,

— the third with lime in a ratio of 1:1.5.

The samples were placed in a muffle furnace at 1100°C and calcined for 3 hours. After receiving the samples, chemical analysis was performed to determine the amount of product obtained. The analysis revealed that the sample with lime in a ratio of 1:1 was the most optimal, as it increased the copper and zinc content. The copper content increased from 0.08% to 0.13%, the zinc content from 0.028% to 0.055%, and the iron content decreased from 6.37% to 4.18%.

Based on precise analyses of the copper processing plant waste composition and a study of the process kinetics, it can be theoretically proven that lime is the most effective compound for reducing iron silicate levels.

CONCLUSION.

This article analyzes copper processing plant waste and determines its mineralogical composition. Initial data showed that the copper content was 0.08%,

ISSN 3030-3907

zinc 0.028%, and iron 6.37%. The kinetics of the substances were studied: three samples were prepared, each supplemented with different stoichiometric amounts of lime, and the process was analyzed. The results showed that the copper and zinc contents increased, while iron decreased: copper increased by 0.62%, zinc by 0.51%, and iron decreased by 1.52%. Thus, it was established that the addition of lime has a positive effect on the process, contributing to an increase in copper and zinc content and a decrease in iron content in the waste.

REFERENCES

1. K. Sanakulov. Scientific and Technical Foundations of Mining and Metallurgical Waste Processing. Monograph. 405 p.
2. Khoshimkhanova, M., Dekhkanov, Z., Yusupova, G., Nimchik, A., Sarikulov, M., Rakhmonov, I., ... & Samadiy, M. (2025). Technology for Obtaining Potassium Nitrate by Processing Brucite from the Navbahor Deposit with Nitric Acid and Converting it with Potassium Chloride. In *E3S Web of Conferences* (Vol. 645, p. 01004). EDP Sciences.
3. A.S. Khasanov, K.S. Sanakulov, A.A. Yusupkhodjaev. Non-ferrous metallurgy. 2010. – 287 p.
4. N.I. Utkin. Metallurgy of Non-Ferrous Metals. Moscow: Metallurgy, 1988. – 440 p.
5. K.V. Bulatov. Technological Capabilities of Metallurgical Processing of Intermediate Products of Polymetallic Ores and Slag Depletion from Copper Smelting in the Pobeda Unit. Polytech Journal. – 2020. – vol. 24, no. 2 (151). – pp. 421-433.
6. Shukhratkodir Toshmatovich, G. (2025). STUDY OF LOCAL RAW MATERIALS FOR PRODUCING CATALYST CARRIERS. *Austrian Journal of Technical & Natural Sciences*.
7. Barros, K.S.; Vielmo, V.S.; Moreno, B. G.; Riveros, G.; Cifuentes, G.; Bernardes, A.M. Chemical Composition Data of the Main Stages of Copper Production from Sulfide Minerals in Chile: A Review to Assist Circular Economy Studies. Minerals 2022, 12, 250. https://doi.org/ 10.3390/min12020250.
8. Tao Chen a b, Chang Lei a b, Bo Yan a, Xianming Xiao a. Metal recovery from the copper sulfide tailing with leaching and fractional precipitation technology. Hydrometallurgy. Volumes 147–148, August 2014, Pages 178–182.
9. A. Aksil. Preliminary study of acid leaching of pyrite copper ore at the Kure copper mine, Turkey. Mining Engineering. Volume 15, Issue 12, December 2002, Pages 1193–1197.

ISSN 3030-3907

10. G. K. Makasheva, L. M. Karimova, B. S. Baimbetov, S. V. Mamyachenkov. Research on the enrichment of old tailings to obtain rough copper concentrate. Mining Journal of Kazakhstan, No. 8, 2024.
11. S.B. Mirzajonova, M.I. Muratova, U.N. Rakhmatov, N.B. Lutfullayeva, G.B. Beknazarova, Z.T. Matkarimov, S.T. Matkarimov. Iron recovery technology from Copper Processing Plants. Advances in Science and Technology. Submitted: 2023-08-23. ISSN: 1662-0356, Vol. 141, pp. 103-109. Revised: 2023-11-07©. https://www.researchgate.net/publication/378942745.
12. S.B.Mirzajonova, X.Sh.Raximov, M.O.Esonova, Sh.N.Jabborova. Technology for recovering metals from industrial waste. 2025. ISBN 2181-3442. 58-62 b.

ISSN 3030-3907