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ФАН ВА ТАЪЛИМ

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**CHARACTERISTICS OF THE RAW, INTERMEDIATE, AND FINAL PRODUCTS IN THE PRODUCTION OF ZINC OXIDE**

**Kazakhbaev S<sup>1</sup>., Rakhimkulov Sh<sup>2</sup>., Davlatov F<sup>3</sup>., Samadiy M<sup>3</sup>., Kholov I<sup>4</sup>., Sultonov A<sup>4</sup>.**

<sup>1</sup>*Karakalpak state university, Republic of Uzbekistan, Nukuc city*

<sup>2</sup>*Tashkent institute of chemical technology, Republic of Uzbekistan, Tashkent*

<sup>3</sup>*Karshi State Technical University Republic of Uzbekistan, Karshi city*

<sup>4</sup>*Tashkent State Technical University*

*E-mail: [shokir0595@mail.ru](mailto:shokir0595@mail.ru)*

*[ilxomxolov775@gmail.com](mailto:ilxomxolov775@gmail.com)*

**Summary:** *This study presents the characteristics of the raw, intermediate, and final products involved in the production of zinc oxide (ZnO). Particular attention is given to the chemical composition, physical properties, and functions of each component at various stages of the technological process. The raw materials considered include zinc concentrate, hydrochloric acid, zinc hydroxide, urea, and redox reagents such as calcium oxide and calcium hypochlorite. The intermediate compounds include zinc chloride, zinc hydroxide, and zinc carbonate formed during the reaction. The final product is high-purity zinc oxide with a ZnO content of not less than 99.62%, used in various industrial sectors. This characterization provides a deeper understanding of the synthesis stages and allows for better control of the final product quality.*

**Key words:** *zinc concentrate, polymetallic ores, sphalerite, beneficiation technology, physicochemical analysis, inorganic, zinc oxide.*

**Introduction:** In various sectors of modern industry, zinc (Zn) and its compounds are gaining increasing importance. The demand for zinc continues to grow steadily across multiple fields such as chemical manufacturing, electrical engineering, pharmaceuticals, metallurgy, and many others. This rising demand underscores the scientific and practical necessity of thoroughly studying zinc-bearing raw materials, optimizing their processing, and obtaining high value-added products.

Uzbekistan possesses significant natural reserves rich in zinc, notably the Khandiza deposit located in the southwestern foothills of the Hisor mountain range in Surkhandarya region. Recognized as one of the major sources of polymetallic ores in Central Asia, the Khandiza deposit contains not only zinc, but also a wide range of valuable and rare metals, including lead, copper, iron, silver, gold, indium, and cadmium [1]. According to available data, the proven reserves of this deposit include approximately 1.5 million tons of zinc, 700 thousand tons of lead, and 180 thousand tons of copper. Additionally, each ton of ore from the deposit contains, on average, 134 grams of silver, 7.24 grams of zinc, 3.5 grams of lead, and 0.86 grams of copper [2].

Currently, zinc concentrates extracted from the Khandiza deposit are processed by the Almalyk Mining and Metallurgical Complex. However, the existing technological processes are unable to recover other valuable elements present in the concentrate, such as copper, silver, gold, indium, and cadmium. Therefore, improving the comprehensive processing of sphalerite-based (ZnS) zinc concentrates has become a matter of critical importance. This improvement requires an in-depth study of the chemical and mineral composition of the concentrates, as well as the implementation of methods to efficiently extract the maximum amount of useful components.

In this study, zinc concentrates obtained from the Khandiza deposit were thoroughly examined. A range of advanced analytical techniques were employed to determine their physicochemical properties. For instance, the zinc content was determined using X-ray fluorescence spectroscopy [3,4], a highly accurate, reproducible, and environmentally friendly non-destructive method that enables the detection of a broad spectrum of elements (from beryllium to uranium) in samples of various physical states [5,6].

In addition, the presence and quantities of elements such as potassium, sodium, chlorine, calcium, magnesium, and sulfates, as well as the water content in solid phases, were analyzed. The quantitative and qualitative analyses were conducted using various classical and instrumental methods, including potassium perchlorate precipitation in ethanol, flame photometry, mercurimetric titration, complexometric and gravimetric methods, and thermal drying. For identifying solid phases, techniques such as chemical analysis, X-ray phase and X-ray fluorescence spectroscopy, infrared (IR) spectroscopy, and microscopic analysis were extensively utilized [7].

These analyses were carried out using advanced instruments such as the Shimadzu XRD-6100 X-ray diffractometer, IRAffinity-1 IR spectrometer, Zetium X-ray fluorescence spectrometer [8], Leica DM500 microscope, and the ICPE-9000 inductively coupled plasma atomic emission spectrometer [9,10].

The results of the research provide a strong scientific foundation for the comprehensive processing of Khandiza concentrates. Not only does this enable the efficient recovery of high-purity zinc, but it also opens the possibility of extracting other valuable elements contained in the ore. Consequently, this work considers the Khandiza zinc concentrate as a strategic raw material for the development of zinc oxide production technology [11].

**Object and Methods of Research:** Polymetallic ores containing zinc (Zn) from the Khandiza deposit, located in the southwestern foothills of the Hisor mountain range in Surkhandarya region, Central Asia, were selected as the subject of this study.

This research focused on the zinc concentrates obtained through the processing of ores extracted from the Khandiza deposit. In Uzbekistan, these polymetallic ores are processed at the Almalyk Mining and Metallurgical Complex, resulting in the production of zinc concentrates.

The polymetallic ores from the Khandiza deposit are characterized by a complex composition, containing not only zinc but also valuable metals such as lead, copper, iron, and silver. Over 100 minerals have been identified in the ores from this deposit. The main inorganic mineral is quartz, which constitutes approximately 80–90% of the total inorganic content. The amount of aluminosilicates ranges from 2–10%. Depending on the sulfide content, the ores are classified into three types: massive (containing 50–95% sulfides), vein-disseminated (10–20%), and mixed (less than 50%).

Given the volume of zinc concentrate production, there is an urgent need to improve the technology for comprehensive processing of sphalerite-based concentrates. This is particularly important because the currently produced zinc concentrate contains other valuable metals—such as gold, silver, indium, cadmium, and copper—which are not being recovered under the existing processes.

The proven reserves of the Khandiza deposit include approximately 1.5 million tons of zinc, 700 thousand tons of lead, and 180 thousand tons of copper. According to international ore classification standards, the total ore reserves of the deposit amount to 14.4 million tons, with each ton containing, on average, 134 g of silver, 7.24 g of zinc, 3.5 g of lead, and 0.86 g of copper. Additionally, the ores contain elements such as selenium, indium, cadmium, and gold. Based on current global market prices, the estimated economic value of the deposit is approximately 4.5 billion USD.

For experimental work, a zinc concentrate was selected, as it is the most suitable raw material for obtaining zinc chloride. During the ore enrichment process, associated minerals are removed, making the concentrate more chemically suitable.

**Results and Discussion:** According to physicochemical analysis, the Khandiza zinc concentrate contains at least 39.45% zinc, up to 3.06% lead, up to 0.80% copper, and up to 13.5% silicon. The chemical composition of the Khandiza concentrate used in this study is as follows (in mass %): Zn – 39.45–40.50, Si – 13.00–13.50, K – 0.95–0.96, Ca – 0.56–0.59, Fe – 1.60–1.65, Cu – 0.78–0.82, Cd – 0.40–0.42, and Pb – 3.00–3.06.

To conduct research on the development of a zinc oxide production technology from the Khandiza concentrate, 10 kilograms of sample materials with varying chemical compositions were selected. The results of the X-ray fluorescence analysis are presented in Table 1.

**Table 1**

**Table 1. Chemical composition of zinc-containing ore and concentrate from the Khandiza deposit**

Chemical composition, wt.%													
№	Name of raw material	Si	K	Ca	Ti	Mn	Fe	Co	Cu	Zn	Mo	Cd	Pb
1	Raw ore	25,0	3,4	1,1	0,08	0,03	3,39	0,01	0,70	5,03	<0,003	0,08	2,27
2	Concentrate	13,0	0,96	0,58	<0,01	<0,01	1,60	<0,01	0,78	39,45	0,034	0,40	3,00
3	Concentrate	13,5	0,96	0,57	<0,01	<0,01	1,60	<0,01	0,80	40,50	0,033	0,41	3,06

**Conclusion:** This scientific study conducted an in-depth investigation of the zinc-bearing polymetallic ores of the Khondiza deposit, located in the mineral-rich southern region of Uzbekistan. Situated in the southwestern foothills of the Hisar range, this deposit was once again confirmed as a natural treasure trove, enriched not only with zinc but also with valuable metals such as lead, copper, silver, cadmium, and indium.

In conclusion, this research provided a significant scientific foundation for a detailed study of the unique geological structure of the Khondiza deposit, the development of new technologies based on zinc concentrates, and the enhancement of economic efficiency. It serves not only as a thorough analysis of Uzbekistan's mineral raw material base but also as a solid cornerstone for the future sustainable development of a modern metallurgical industry.

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**Rezyume:** Ushbu tadqiqot rux oksidi (ZnO) ishlab chiqarishda qo'llaniladigan xomashyo, oraliq va yakuniy mahsulotlarning xususiyatlarini taqdim etadi. Texnologik jarayonning turli bosqichlarida har bir tarkibiy qismning kimyoviy tarkibi, fizik xossalari va vazifalariga alohida e'tibor qaratilgan. Ko'rib chiqilgan xom ashyolarga rux konsentrati, xlorid kislotasi, rux gidroksidi, mochevina hamda kalsiy oksidi va kalsiy gipoxlorit kabi oksidlanish-qaytarilish reagentlari kiradi. Oraliq birikmalar sifatida reaksiya davomida hosil bo'lgan rux xlorid, rux

gidroksid va rux karbonat ko'rsatilgan. Yakuniy mahsulot esa ZnO miqdori 99,62% dan kam bo'lmagan yuqori tozalikdagi rux oksidi bo'lib, u sanoatning turli sohalarida qo'llaniladi. Ushbu tavsif sintez bosqichlarini chuqurroq tushunish imkonini beradi va tayyor mahsulot sifatini yaxshiroq nazorat qilishga yordam beradi.

**Резюме:** В данной работе представлена характеристика исходных, промежуточных и конечных продуктов, участвующих в процессе получения оксида цинка (ZnO). Основное внимание уделено химическому составу, физическим свойствам и функциям каждого компонента на различных этапах технологического процесса. В качестве исходных веществ рассмотрены цинковый концентрат, соляная кислота, гидроксид цинка, карбамид, а также окислительно-восстановительные реагенты, такие как кальций оксид и гипохлорит кальция. Промежуточные соединения включают хлорид цинка, гидроксид цинка и карбонат цинка, образующиеся в ходе реакции. Конечным продуктом является высокочистый оксид цинка с содержанием ZnO не менее 99,62%, используемый в различных отраслях промышленности. Данная характеристика позволяет более глубоко понять этапы синтеза и контролировать качество получаемого продукта.

**Kalit so'zlar:** rux konsentrati, polimetall rudalar, sfalerit, boyitish texnologiyasi, fizik-kimyoviy tahlil, noorganik, rux oksidi.

**Ключевые слова:** цинковый концентрат, полиметаллические руды, сфалерит, технология обогащения, физико-химический анализ, неорганический, оксид цинка.