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INVESTIGATIONS OF ROASTING PROCESS AND FRACTIONAL COMPOSITION OF ZINC CONCENTRATE OF KHANDIZA DEPOSIT

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The aim of the study is to study the effect of the process of calcining zinc concentrate from the Khandiza deposit on the degree of zinc extraction and fractional composition. For this, the chemical composition of the concentrate was established and it was shown that the main components are zinc, silicon, potassium, calcium, iron, copper, cadmium, and lead. Titanium, manganese, cobalt, and molybdenum are also contained in small amounts.

Extraction of zinc from a concentrate, calcined at 900 °C for 90 minutes with sulfuric acid with concentration of 18-25% in an autoclave at a temperature of 75 °C, a ratio of Zn:H_2SO_4=1:1.05 and process duration of 90 minutes allows achieving the degree of extraction – 91%.

The optimum roasting temperature of the concentrate is 900 °C and the duration of calcination is 90 minutes.

The main part of 92.1% zinc-containing concentrate calcined under optimal conditions is a fraction of -0.140 mm and 3.6% of fraction of -0.165 – + 0.140 mm.

The possibility of obtaining zinc sulfate from the zinc-containing concentrate of the Khandiza deposit is shown. To do this, the calcination process must be carried out at a temperature of 900 °C and a process duration of 90 minutes. The degree of extraction of zinc increases from 71% to 91%.

Keywords: zinc concentrate, calcination, extraction degree, zinc sulfate, sulfuric acid

ИССЛЕДОВАНИЯ ПРОЦЕССА ОБЖИГА И ФРАКЦИОННОГО СОСТАВА ЦИНКОВОГО КОНЦЕНТРАТА МЕСТОРОЖДЕНИЯ ХАНДИЗА

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Целью исследования является изучение влияния процесса прокалки цинкового концентрата месторождения Хандиза на степень извлечения цинка и фракционный состав. Для этого установлен химический состав концентрата и показано, что основными компонентами являются цинк, кремний, калий, кальций, железо, медь, кадмий, свинец. Содержатся также в незначительных количествах титан, марганец, кобальт, молибден.

Извлечение цинка из концентрата, прокаленного при 900 °С в течение 90 минут серной кислотой с концентрацией 18-25% в автоклавном режиме при температуре 75 °С, соотношении Zn:H_2SO_4=1:1,05 и продолжительности процесса 90 минут позволяет достичь степени извлечения 91%.

Оптимальной температурой обжига концентрата является 900 °С и продолжительность прокалки 90 минут.

Основную долю, прокаленного при оптимальных условиях цинксодержащего концентрата 92,1%, составляет фракция -0,140 мм и 3,6% фракция -0,165 – + 0,140 мм.

Показана возможность получения сульфата цинка из цинксодержащего концентрата месторождения Хандиза. Для этого процесс прокалки необходимо проводить при температуре 900 °С и продолжительности процесса 90 минут. При этом степень извлечения цинка повышается с 71% до 91%.

Ключевые слова: цинксодержащий концентрат, прокалка, степень извлечения, сульфат цинка, серная кислота

XONJIZA KONI RUX SAQLOVCHI KONSENTRATINI KUYDIRISH JARAYONI VA FRAKSION TARKIBINI TADQIQ ETISH

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Tadqiqotning maqsadi - Xanjiza konining rux konsentratini kalsinlash jarayonini rux olish darajasi va uning fraksiyonal tarkibiga ta'sirini o'rganish. Buning uchun kontsentratning kimyoviy tarkibi aniqlandi va asosiy komponentlar rux, kremniy, kaliy, kaltsiy, temir, mis, kadmiy, qo'rg'oshin ekanligi ko'rsatildi. Titan, marganets, kobalt, molibden ham oz miqdorda mavjud.

Avtoklav rejimida konsentratsiyasi 18-25% bo'lgan sulfat kislota bilan 90 minut davomida 900 °C da kalsifikatsiyalangan konsentratdan ruxni 75 °C haroratda, Zn:H_2SO_4=1:1,05 nisbatda va jarayon davomiyligi bilan ajratib olish. 90 daqiqa 91% ekstraktsiya darajasiga erishish imkonini beradi.

Konsentratlarni yoqish uchun optimal harorat 900 °C, kalsinlanish muddati esa 90 minut.

Optimal sharoitlarda kaltsiylangan rux o'z ichiga olgan konsentratning asosiy ulushi 92,1% fraktsiya -0,140 mm va 3,6% fraktsiya -0,165 - + 0,140 mm.

Xondiza konining tarkibida rux bo'lgan konsentratdan rux sulfat olish imkoniyati ko'rsatilgan. Buning uchun kalsinatsiya jarayoni 900 °C haroratda va jarayonning davomiyligi 90 daqiqada amalga oshirilishi kerak. Ruxni olish darajasi 71% dan 91% gacha oshadi.

Kalit so'zlar: rux konsentrati, kuydirish, ajratib olish darajasi, rux sulfati, sulfat kislota

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Introduction

Zinc sulfate (zinc sulfate heptahydrate $ZnSO_4 \cdot 7H_2O$, zinc sulfate) is used as a trace element, as a mineral feed additive, in the production of mineral paints, as a bleach for paper, in the production of various medicines, in metallurgy, electroplating, the production of yeast, beer, leather products, wood impregnation [1-4].

Sphalerite is one of the main raw materials for the production of zinc, which is usually in the sulfide state. Metallic zinc is smelted from sphalerite, and Cd, In, Ga, and other valuable components are extracted along the way [5]. Sphalerite is used in paint and varnish production for the manufacture of zinc oxide, and it is used to obtain brass. Great importance is the production of chemically pure ZnS, activated Ag, Cu from natural sphalerite, which is used for the manufacture of phosphors, various light compositions and luminous paints. In addition, natural sphalerite is used as a photocatalyst for the decomposition of dyes in water [6–8].

Zinc sulphate is produced in conjunction with manufacturing processes for other zinc containing products. It is obtained by treating mineral ores, zinc ash, and processed products containing metallic zinc or zinc oxide with sulfuric acid, followed by filtration, crystallization, grinding, and packaging [9 –12].

Global zinc production in 2019 was estimated at 13 million tons growing up to 4% from 2018. A noticeable increase in zinc production occurred in Australia, China and South Africa [13-16]. In Australia, the Woodlawn tailings project opened in 2017 and significant production growth has occurred at the Dugald River and Lady Loretta mines, as well as two tailings projects launched in 2018. In South Africa, production increased at the Gamsberg mine, which came online at the end of 2018. According to the International Lead and Zinc Study Group, global production of refined zinc in 2019 was estimated at 13,49 million tons and consumption at 13,67 million tons, resulting in a gap between production and consumption of approximately 180,000 tons of refined zinc [17-18]. Domestic zinc production declined in 2019 in part due to the closure of the Pend Oreille mine in Washington State after current reserves were depleted. The mine was reopened in 2014 after being closed since 2009. Apparent US refined zinc consumption rose to a 5-year high of 950,000 tons in 2019. The estimated average annual price of special, high quality zinc in North America decreased by 11% in 2019 compared to 2018, or $1.25 per pound [19-25].

Research methods

The studies were carried out on the zinc-containing concentrate of the Khandiza deposit with a zinc content of 45,15-45,45%. Chemical analysis of initial, intermediate, and final products was carried out by known methods [26–30].

Zinc was determined by the X-ray fluorescence method [31]. The method is based on the collection and subsequent analysis of the spectrum that occurs when the studied material is irradiated with X-rays - this is a fast, non-destructive and environmentally friendly method of analysis with high accuracy and reproducibility of results. The method allows qualitatively, semi-quantitatively and quantitatively to determine all elements from beryllium to uranium, which are in powder, solid and liquid samples.

Electron microscopy was performed on a Leica DM500 instrument, Germany. The device makes it possible to study the microstructures of solids, their local compositions, and microfields (electric, magnetic, etc.) using electron microscopes (EM), devices that use an electron beam to obtain magnified images [32].

X-ray phase analysis was performed on a Shimadzu XRD-6100 diffractometer, which is used for X-ray phase analysis, analysis of the crystallinity degree, stress analysis, retained austenite, and many other tasks. The ability to use any X-ray tubes that meet the European standard, as well as a wide range of additional attachments, makes the XRD-6100 X-ray diffractometer universal and suitable for solving any analytical problems. The device has software that allows you to collect, store, interpret and process data, monitor the state of the diffractometer, qualitative and quantitative phase analysis and other studies, convert experimental data files into text formats, and create your own data libraries. The XRD-6100 diffractometer with a vertical θ-2θ goniometer is designed to solve most applied and research problems [33].

Results and discussion

The studies were carried out with zinc-containing concentrate from the Khandiza deposit. The roasting process of zinc concentrates was carried out to transfer base metals and sulfur from sulfide compounds to oxidized states.

For experiments, zinc-containing concentrate from the Khandiza deposit of the following chemical composition (mass %) was used: Zn - 45,15-45,45; Si - 12,90-13,30; Mn - 0,1; Fe - 1,57-1,64; Mo - 0,031-0,033; Pb - 3,01-3,05 and technical sulfuric acid with a concentration of 92,5%.

In order to improve the technology for processing polymetallic raw materials and develop a strategy for complete, integrated processing, data from a detailed study of the mineralogical and chemical composition of zinc-containing concentrates from the Khandiza deposit, which contain a number of valuable components, are required.

Chemical analysis showed that the zinc-containing concentrate of the Khandiza deposit has a complex chemical composition. The analyzes were carried out as follows: 200 mg of the concentrate were weighed on an analytical balance (FA220 4N). For mineralization, a mineralization device (MILESTONE Ethos Easy, Italy) was used. To do this, the test tube of the device was filled with a sample (200 mg), 6 ml of distilled, purified nitric acid (HNO_3) was added by distillation, i.e. in an infrared acid purifier (Distillacid BSB-939-IR) and 2 ml of hydrogen peroxide (H_2O_2) as an oxidizing agent. The whole mixture turns into a mineral within 40 minutes.

At the end of the mineralization process, the mixture was transferred into a separate conical flask and diluted with distilled water to a volume of 40 ml (BIOSAN, Latvia).

Then the solution from the flask was placed into special test tubes in the automatic sampling section of the instrument and put for analysis. The prepared samples were analyzed on an Avio200 ICP -OES inductively-coupled plasma optical emission spectrometer (Perkin Elmer, USA). The accuracy of the device is high, which makes it possible to measure elements in solution with an accuracy of up to RSD ≤ 0.1%.

Table 1 shows the data of optical emission spectrometric analysis of zinc concentrate from the

Table 1

Results of X-ray fluorescence optical emission spectrometric analysis of zinc concentrate from the Khandiza deposit

No. of samples	Content of elements, %											
	Zn	Si	K	Ca	Ti	Mn	Fe	C	Cu	Mo	Cd	Pb
1	45,30	12,90	0,94	0,55	<0,01	<0,01	1,64	<0,01	0,81	0,032	0,40	3,03
2	45,45	13,10	0,94	0,58	<0,01	<0,01	1,61	<0,01	0,79	0,031	0,41	3,04
3	45,15	13,25	0,95	0,57	<0,01	<0,01	1,59	<0,01	0,77	0,033	0,39	3,01
4	45,35	13,30	0,95	0,56	<0,01	<0,01	1,57	<0,01	0,79	0,032	0,40	3,05

Khandiza deposit.

The Table 1 shows that the main components are zinc, silicon, potassium, calcium, iron, copper, cadmium, lead. There are also, in small amounts, titanium, manganese, cobalt, molybdenum. The content of components in the concentrate, regardless of the selected sample, is almost the same. Thus, the zinc content is 45,15-45,45%, silicon 12,90-13,30%, potassium 0,94-0,95%, calcium 0,55 -0,58%, iron 1.57-1 .64%, copper 0,77-0,81%, cadmium 0,39-0,41%, lead 3,01-3,05%. The contents of the remaining components do not exceed 0,01%, with the exception of 0,033% molybdenum.

Studies on the production of zinc sulfate from a concentrate by decomposition with sulfuric acid in an autoclave mode showed that the degree of extraction of zinc with duration of the leaching process of up to 10 minutes does not exceed 65%. The maximum degree of extraction of zinc into the solution reaches 91% at a temperature of 75 °C, a process duration of 90 minutes, a ratio of Zn:H_2SO_4=1:1,05, a concentrate calcination temperature at 900 °C, and a process duration of 90 minutes. The impurities of compounds of lead, silicon, and other elements found in the concentrate do not dissolve in sulfuric acid and form impermeable crusts on the surface of zinc raw materials. To prevent this phenomenon, studies of the effect of precalcination of zinc concentrate were carried out. The process was carried out in a muffle furnace at temperatures of 400-1000 °C and a calcination time of 30-180 minutes.

Figure 1 shows the results of the influence of the zinc concentrate calcination temperature on the degree of zinc extraction at Zn:H_2SO_4=1:1,05, temperature 75 °C and the duration of the autoclave leaching process 90 minutes.

An increase in the calcination temperature of the zinc concentrate from 400 °C to 900 °C promotes an increase in the degree of zinc extraction into the sulfuric acid solution from 71 to 90%. A further increase in temperature does not affect the degree of extraction. The conducted experiments show that the optimal firing temperature is 900 °C.

With an increase in the duration of the calcination process from 10 to 90 minutes, the degree of zinc extraction increases from 65 to 90%. A further increase in temperature does not affect the degree of extraction of zinc from the zinc-containing concentrate. Experiments carried out show that the optimal firing time is 90 minutes (Fig. 2).

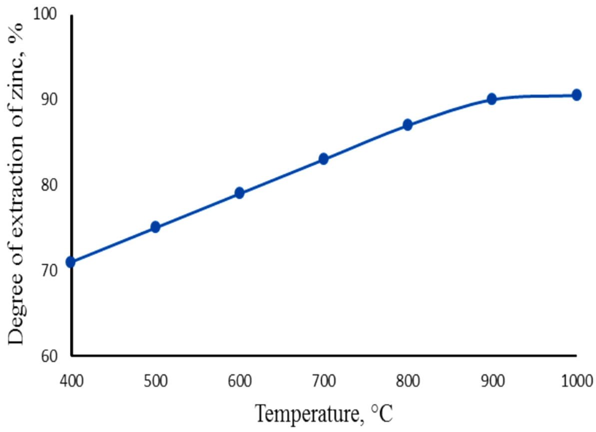

Figure 1. Influence of calcination of zinc-containing concentrate on the degree of zinc extraction.

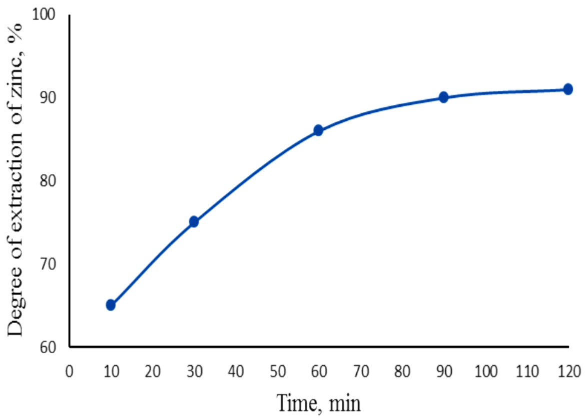

Figure 2. Influence of the duration of the calcination process of a zinc-containing concentrate on the degree of zinc extraction.

In order to identify the effect of the particle size of the zinc-containing concentrate from the Khandiza deposit, the analysis of the concentrate after firing at 900 °C, time 90 minutes was carried out. It has been established that the zinc content ranges from 45% to 47%, silicon from 12,90% to 13,30%, copper from 0,79% to 0,81%, cadmium from 0,39% to 0,41%.

To determine the distribution of zinc depend-

Table 2
Fractional and chemical composition of the zinc-containing concentrate of the Khandiza deposit after roasting

Grain size, mm	Fraction content, %	Chemical composition, wt. %		
		Zn	Si	H_2O
+0,90	0,2	45,05	15,65	0,47
-0,90 ÷ +0,65	0,3	45,14	14,81	0,48
-0,65 ÷ +0,50	0,5	45,31	14,11	0,47
-0,50 ÷ +0,25	1,2	45,39	13,25	0,49
-0,25 ÷ +0,165	2,1	45,54	12,47	0,51
-0,165 ÷ +0,140	3,6	45,67	11,28	0,48
-0,140	92,1	46,11	10,15	0,49

ing on the size of the fraction, the fractional and chemical composition of the zinc-containing concentrate of the Khandiza deposit, calcined at 900 °C and the process duration of 90 minutes, was studied (Table 2).

The Table 2 shows that the main share of the zinc-containing concentrate of the Khandiza deposit is a fraction of -0.140 mm, which, with a decrease in the size of the fraction, increases from 0,2% to 92,1% for a concentrate with a content of 45,45% Zn and 13,10% Si.

The increase in the zinc content is due to a decrease in the content of silicon in the concentrate from 15,65% in the +0,90 mm fraction to 10,15 in the -0,140 mm fraction. The main content of silicon is observed in fractions from +0,90 mm to +0,25 mm.

Figure 3 shows that with a decrease in the size of the fractions of the zinc-containing concentrate from the Khandiza deposit, the degree of extraction increases and amounts to 91,7% for the -0,140 mm fraction. With an increase in particle size to 0,90 mm, the degree of extraction decreases to 78,0%. The conducted studies show that with a decrease in the particle size of the zinc-containing concentrate from the Khandiza deposit, the degree of extraction will increase. This is due to the fact that the smaller the particle size, the greater the degree of contact of the acid with zinc in the concentrate and, accordingly, the high reaction rates.

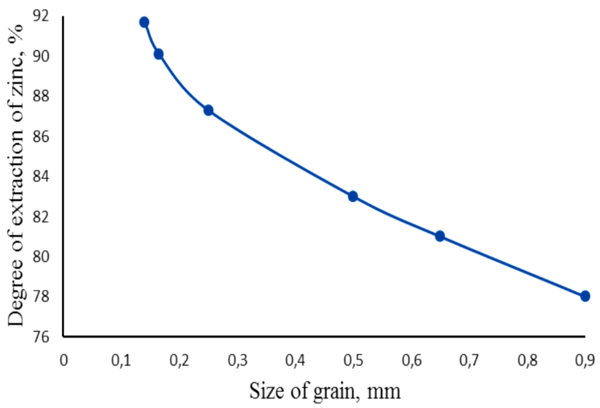

Figure 3. Influence of particle size of zinc-containing concentrate on the degree of zinc extraction.

Conclusion

Thus, the conducted studies showed the possibility of obtaining zinc sulfate from the zinc-containing concentrate of the Khandiza deposit by leaching zinc with sulfuric acid in an autoclave mode. To do this, the zinc concentrate must first be calcined at 900 °C for 90 minutes and zinc should be leached with sulfuric acid from a fine -0,140 mm fraction. The degree of extraction of zinc reaches 91,7%.

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