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Research Article

The application of analytical methods for determining the rational composition of lead and zinc concentrate

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Abstract:

Unlike other metals, Pb and Zn are not found free in nature but in the form of their minerals, from which they are extracted. Sulfide and oxide minerals of Pb exist in nature. Galena (PbS) is the most widespread sulfide mineral and is the most important Pb mineral, while cerussite ($PbCO_3$) is a significant Pb oxide mineral. Pb mineral deposits are composite, containing considerable amounts of Zn minerals. Therefore, Pb minerals are often referred to as Pb-Zn (lead-zinc) minerals. In smaller quantities, these deposits also contain minerals of other metals such as Fe, Cu, Sn, Sb, Cd, Bi, As, Ag, and Au, as well as trace amounts of rare metals. Zn minerals also exhibit sulfide and oxide characteristics. Many Zn-containing minerals exist in nature, but those of industrial importance include ZnS (sphalerite), mZnS·nFeS (marmatite), and ZnO (zincite). The process of obtaining lead and zinc primarily involves ore preparation through various processing methods to obtain either a collective lead-zinc concentrate or separate lead and zinc concentrates. After extracting the lead or zinc concentrate, the smelting process follows to produce the raw metal. If pure metal is required, it undergoes a refining process.

1. Introduction

Lead (Pb) and zinc (Zn) are crucial metals found in nature primarily as minerals, rather than in their free forms. The most significant lead mineral is galena (PbS), a sulfide mineral, with cerussite ($PbCO_3$) being an important oxide mineral. Lead deposits typically contain substantial amounts of zinc minerals, often classifying them as lead-zinc (Pb-Zn) deposits [1,2,3]. These deposits can also include trace amounts of metals such as iron (Fe), copper (Cu), tin (Sn), silver (Ag), and gold (Au). Zinc minerals of industrial importance include sphalerite (ZnS), marmatite (mZnS·nFeS), and zincite (ZnO). The extraction process for lead and zinc involves ore preparation, where the minerals are concentrated before being smelted to produce raw metal, which may then be refined to achieve the desired purity [4,5].

2. Material and Methods

In this study, the elemental composition of lead (Pb) and zinc (Zn) concentrates was determined using an analytical method. The concentrates, derived from the flotation process of Pb-Zn minerals, were analyzed for their elemental components. The investigation included calculating the content of various compounds and elements in the concentrate, particularly Pb and Zn. The analytical method used allows for the calculation of the rational composition of the concentrate, essential for further metallurgical processes such as smelting and refining. These calculations were performed on a 100 kg sample of concentrate, and the results were presented in tabular form to ensure clarity and precision.

3. Results and Discussions

Elemental composition of Pb-Zn concentrate in %:

$$Pb = 50.5\%$$

$$Zn = 11.4\%$$
$$Cu = 2.9\%$$
$$Fe = 8.1\%$$
$$S = 20.8\%$$
$$SiO_2 = 1.8\%$$
$$CaO = 1.3\%$$
$$Al_2O_3 = 1.4\%$$

Metals in the concentrate are found in the form of these compounds:
$Pb \rightarrow PbS,\ Zn \rightarrow$ i $ZnS, Cu \rightarrow Cu_2S$, $Fe \rightarrow FeS$ and FeS_2
$CaO \rightarrow CaCO_3$.
Calculations are made in 100 kg concentrate.

Quantity of PbS in concentrate: PbS^k,
Quantity S in PbS: S_{PbS}
Quantity S in ZnS: S_{ZnS}
Quantity S in Cu_2S: S_{Cu_2S}
Quantity Cu_2S in concentrate: Cu_2S^k,
Quantity S in concentrate: S^k,
Quantity S in concentrate: FeS: S_{FeS}
Quantity S in concentrate: FeS_2: S_{FeS_2} ,
Quantity Fe in concentrate: Fe^k.

$$PbS^k = \%Pb \times \frac{PbS}{Pb} = 50.5 \cdot \frac{239}{207} = 58.3\%,\ [kg]$$
$$S_{PbS} = 50.5 \times \frac{S}{Pb} = 50.5 \cdot \frac{32}{207} = 7.8\ [kg]$$
$$S_{ZnS} = \%Zn \times \frac{S}{Zn} = 11.4 \cdot \frac{32}{65} = 5.6\ [kg]$$
$$ZnS^k = Zn + S = 11.4 + 5.6 = 17\ [kg]$$

$$\boldsymbol{ZnS^k = 17\ [kg]}$$

$$S_{Cu_2S} = \%Cu \times \frac{S}{2Cu} = 2.9 \cdot \frac{32}{2 \cdot 63.5} = 0.73\ [kg]$$
$$Cu_2S^k = \%Cu \times \frac{Cu_2S}{2Cu} = 2.9 \cdot \frac{159}{2 \cdot 63.5} = 3.63\ [kg]$$

$$\boldsymbol{Cu_2S^k = 3.63\ [kg]}$$

$$\sum S^k = S_{PbS} + S_{ZnS} + S_{Cu_2S} + S(FeS + FeS_2)$$
$$S(FeS + FeS_2) = \sum S^k - S_{PbS} - S_{ZnS} - S_{Cu_2S}$$

$$S(FeS + FeS_2) = 20.8 - 7.8 - 5.6 - 0.73 = 6.67[kg]$$

$$\left.\begin{matrix} S_{FeS} = \boldsymbol{x} \\ S_{FeS_2} = \boldsymbol{y} \end{matrix}\right| \rightarrow \boldsymbol{x} + \boldsymbol{y} = 6.67$$

$$\left.\begin{matrix} Fe^k{}_{FeS} = \boldsymbol{p} \\ Fe^k{}_{FeS_2} = \boldsymbol{q} \end{matrix}\right| \rightarrow \boldsymbol{p} + \boldsymbol{q} = 8.1$$

$$\frac{S}{Fe} = \frac{x}{p} \quad \rightarrow \quad \boldsymbol{p} = \frac{xFe}{S}$$

$$\frac{2S}{Fe} = \frac{y}{q} \quad \rightarrow \quad \boldsymbol{q} = \frac{\boldsymbol{y}Fe}{2S}$$

Balances: $x + y = 6.67$
$p + q = 8.1$

$$x + y = 6.67$$
$$\frac{xFe}{S} + \frac{yFe}{2S} = 8.1$$

$$x + y = 6.67$$
$$1.75x + 0.875y = 8.1$$

$\boldsymbol{y = 4.06}$ and $\boldsymbol{x = 2.61}$

$$p = \frac{xFe}{S} = \frac{2.61 \cdot 56}{32} = 4.56$$
$$q = \frac{yFe}{2S} = \frac{4.06 \cdot 56}{64} = 3.55$$
$$\boldsymbol{q = 3.55}$$

$$S_{FeS} = \boldsymbol{x} = 2.61\ [kg]$$
$$S_{FeS_2} = \boldsymbol{y} = 4.06\ [kg]$$
$$\sum S_{(FeS+FeS_2)} = 2.61 + 4.06 = 6.67\ [kg]$$
$$FeS = 2.61 \cdot \frac{FeS}{S} = 2.61 \frac{88}{32} = 7.17\ [kg]$$
$$\boldsymbol{FeS = 7.17\ [kg]}$$
$$FeS_2 = 4.06 \cdot \frac{FeS_2}{2S} = 4.06 \frac{120}{64} = 7.61\ [kg]$$
$$\boldsymbol{FeS_2 = 7.61\ [kg]}$$
$$CaCO_3 = \%CaO \cdot \frac{CaCO_3}{CaO} = 1.3 \frac{100}{56} = 2.32\ [kg]$$
$$\boldsymbol{CaCO_3 = 2.14\ [kg]}$$

Table 1. *Compostion of concentrate.*

	Pb	Zn	Cu	Fe	S	CaO	SiO_2	Al_2O_3	Others	$\sum$
PbS	50.5				7.8					58.3
ZnS		11.4			5.6					17
Cu_2S			2.9		0.7					3.6
FeS				4.56	2.6					7.16
FeS_2				3.55	4.0					4.61

$CaCO_3$						1.3				1.3
SiO_2							1.8			1.8
Al_2O_3								1.4		1.4
Others									rest	rest
∑	50.5	11.4	2.9	8.1	20.8	1.3	1.8	1.4	rest	100

4. Conclusions

The study successfully determined the rational composition of lead-zinc (Pb-Zn) concentrates, a crucial step in enhancing the efficiency of metallurgical processes. By employing a precise analytical method, the research provided valuable insights into the elemental composition of the concentrates, which is essential for various stages of metal production, such as ore preparation, smelting, and refining. The accurate calculation of lead, zinc, and minor elements such as iron, copper, antimony, and silver allows for more informed decision-making during the metallurgical process, helping optimize the use of raw materials and energy.

One of the key outcomes of the study is its potential to improve the material balance calculations and metallurgical load during smelting. With accurate knowledge of the elemental composition, plant operators can adjust smelting parameters, leading to higher yields and reduced waste. The method also contributes to ensuring the quality of the final metal products by enabling the prediction and control of impurities during refining. This is especially important when extracting high-purity lead and zinc for industrial applications.

Additionally, the study highlights the importance of rational composition calculations in evaluating the economic feasibility of mining and metallurgical projects. By understanding the exact proportions of valuable metals in the concentrate, mining operations can better assess the potential profitability of deposits. This can lead to more targeted mining efforts, minimizing environmental impacts while maximizing resource extraction.

In conclusion, the analytical approach presented in this research not only enhances the understanding of lead and zinc concentrates but also offers practical applications in optimizing metallurgical processes.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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