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Zinc Recovery from Direct Leaching Sulfide Concentrate Residue in Pilot Scale

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1. Introduction

Zinc extraction from sphalerite is one of the big challenges in zinc extraction industry. The pyrometallurgical method has been significantly limited due to the lower boiling point of the pure zinc. In the last decades, the method of roasting-leaching-electrowinning has been used to produce zinc from sulfide concentrate. However, high cost, the formation of unwanted phases during roasting process and environmental pollution are the problems of this method. In the mid-80s, Sherrit-Gordon Corporation used pressure leaching. This method also faces industrial constraints due to higher production costs and complex (and high pressure) equipment during the leaching process. By a wider research conducted by the Auto-Koumpo Company, an efficient method for zinc leaching from sulfide concentrate in atmospheric conditions was proposed. The sphalerite is oxidized under the hydrostatic pressure in the reactor and the elemental sulfur simultaneously is released as a product of the reaction. Different processes, such as physical or mechanical separation by flotation, sulfur hydrophilic modification, and extraction via H2O or CO2 carbohydrates, have been proposed for sulfur removal from leaching residues. In this study, sphalerite residue leaching has been investigated. First, the residue was analyzed and the content of zinc and sulfur in the waste was determined. Then, the material was fed into the pilot tubular reactor and the effect of different factors was investigated at a certain temperature.

2. Materials and Methods

The used residue was executed from direct leaching of Anguran sulfide concentrate in a tubular reactor. The content of zinc, sulfur, lead, and iron in the residue was 32%, 34%, 6.2, and 4.5%, respectively. In this research, industrial Sulfuric Acid (98.5%) and Iron Oxide Sulphat (FeSO4.5H2O) were used. The initial solution was made at 95 °C in the side tank, the residue was added to the solution with a ratio of 20 g/l, and the slurry was pumped into the tubular reactor. By the pulp pump to the tubular reactor, air was blowing from the bottom of the reactor. The reactor height was more than 10 meters and the slurry height was 9 meters. Zinc and iron concentrations in taken samples were determined by atomic absorption (Varian, AA240). X-ray diffraction analysis was used to determine the phases in the sulfide waste. In addition, the structure of the residue was investigated by scanning electron microscopy (SEM).

3. Results and Discussion

3.1. Identification of the initial waste structure. X-ray diffraction analysis was used to investigate the phases in the residue. Sphalerite and sulfur are mainly present in the sludge structure. Other phases such as quartz, jarosite, anglesite, and cadmium compounds are found in the structure. Anglesite is formed due to the reaction of lead with SO42-. Figure 1 shows the microstructure in zinc sulfide sludge before the leaching process. As shown, sulfur is present as an element on the surface and the particles are surrounded by sulfur layer.

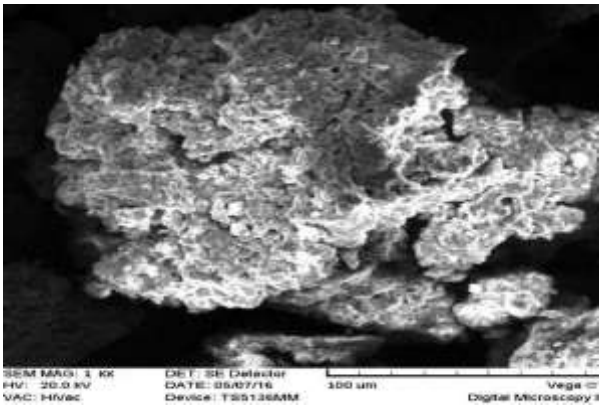

Figure 1. SEM micrograph of primary zinc sulfide waste

2.2. Effect of sulfuric acid concentration . H_2SO_4 directly attack the surface of the sphalerite or increase the rate of ferrous sulfate ($FeSO_4$) oxidation. Leaching of sphalerite was carried out at two 0.5 and 1.5 mol/L of sulfuric acid. In the early hours, sulfuric acid has a favorable effect on zinc dissolution. However, after a while, the dissolution reaches a uniform state at both concentrations. It seems that at first, with increasing acid concentration, the concentration of Fe^{3+} is increased and penetrates through the diffusion paths on the sulfur layer. With the advancement of the reaction, the sulfur is released and blocks the intrusive routes, and the rate of leaching significantly decreases.

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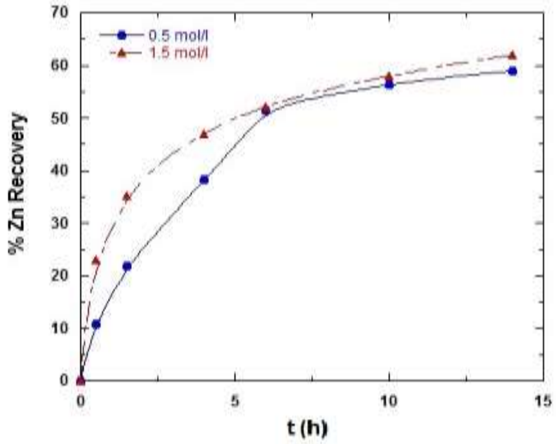

Figure 2. Zn Extraction over time in different H_2SO_4 concentrations

3.3. Effect of iron concentration. Iron is usually bivalent in sulfate solutions, but due to the constant oxidation of Fe^{2+} ions by oxygen gas and ionic ferric generation, the concentration of this ion is directly related to the total iron concentration. Therefore, with increasing total iron concentration, the concentration of ionic ferric is also increased. According to the Nernestat dissolution model, the concentration profile of the dissolution agent (Fe^{3+}) can broadly affect the rate of dissolution. As shown in Figure 3, the effect of Fe concentration on the dissolution is investigated. The Zn leaching rate directly dependeds on Fe concentration. It seems that after 10 hours, the recovery of zinc has decreased to 0.4 mol/L Fe. Whereas, as 0.2 mol/L Fe, the leaching rate is lower and roughly uniform in the sulfate solution.

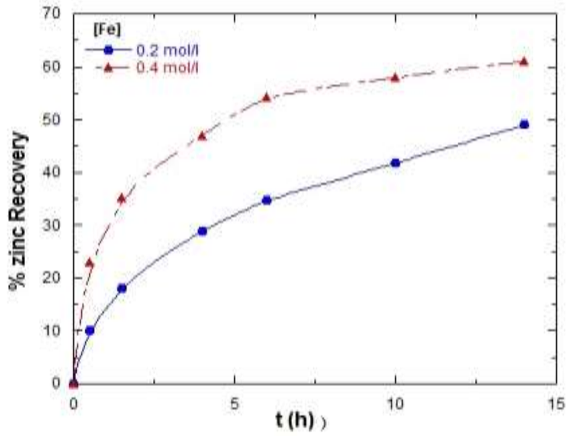

Figure 3. Zn extraction over time in 0.5 mol/L sulfuric acid

3.4. Effect of zinc sulfate concentration. Zinc leaching at 0.01 and 0.5 mol/L $ZnSO_4$ is investigated. According results, increasing concentration of sulfate has no appreciable effect on the dissolution rate.

3.5. Effect of temperature. Residual leaching was carried out at three temperatures 80, 87 and 95 °C. The results were presented in Figure 7. Increasing temperature has increased the recovery of leaching up to 10%. With increasing temperature, the driving force of the reactant mass transfer coefficients (such as the penetration coefficient) is increased. The rate of dissolution increase by temperature.

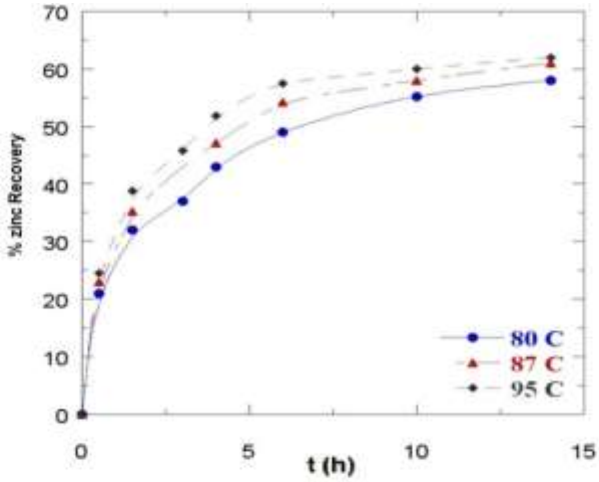

Figure 4. Effect of temperature on the leaching recovery

3.6. Residue leaching kinetic. The kinetics of residue leaching based on the shrinking core model in chemical control and diffusion in the ash layer was investigated. Depending on the detection coefficients (R2), the diffusion in ash layer model was approved as kinetic model ZnS dissolution. As the temperature increased, the process rate increased and the rate constant at 80, 87, 95 °C were calculated at 0.192, 0.23 and 0.278, respectively. In addition, the Arrhenius equation was drawn to calculate the activation energy of sulfide residue leaching. The apparent energy of this process was calculated to be 24.24 kJ / mol.

4. Conclusion

Results showed taht a significant amount of zinc can be extracted from sulfide residue. The concentration of sulfuric acid and iron has a positive effect on dissolution rate. However, with increasing sulfate ion concentration, the extraction percentage does not change significantly. Moreover, the temperature has a favorable effect on the rate of the leaching. The kinetics of the reaction is controlled by diffusion in the ash layer, and as temperature increases diffusion in the ash layer. The apparent activation energy for sulfide residue leaching was calculated 24.24 kJ/mol.