THE KINETICS OF FERRIC CHLORIDE LEACHING OF SPHALERITE IN THE MICROWAVE FIELD①

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ABSTRACT

The kinetics of ferric chloride leaching of sphalerite in the microwave field has being studied in this paper. According to the experimental data, the rate of dissolution of sphalerite microwave irradiation heating is faster than that with conventional heating. The dissolution of sphalerite in the microwave field was investigated in different condition of temperature, concentration of $FeCl_3$ and particle size and a nonisothermal kinetic equation has being obtained.

Key words: Microwave field, ferric chloride, sphalerite, kinetics of leaching

1 INTRODUCTION

Although the kinetics of ferric chloride leaching of sphalerite with conventional heating has been studied[4], yet, the kinetics with microwave irradiation heating has been scarecely reported. In this paper, the kinetics of leaching sphalerite by ferric chloride in the microwave field was experimently investigated for the purpose of utilizing the advantageous characteristics of microwave heating (such as internal heating, high frequency and without additional stirrer, etc.), and improving hydrometallurgical techniques.

2 EXPERIMENT

Experiments were carried out in 650 W and 2,450 MHz refitted commercial microwave oven. As soon as microwave irradiation was finished, temperature was measured immediately by inserting a thermometer into the solution.

According to the blank test, the error factor of the temperature measured with this method is in the range of ± 1℃.

Sphalerite samples contain Zn 48.40, S 25.18, Fe 0.49 and Pb 1.03 wt.−%. Leaching solutions were prepared using CP $FeCl_3 \cdot 6H_2O$, HCl and distilled water. 0.1 M HCl has being used in all of the experiments[1].

3 EXPERIMENTAL RESULTS AND DISCUSSION

3.1 *Comparision of Leaching Rate of Microwave Heating With That of Conventional Heating*

The comparision of leaching rate of microwave heating with that of conventional heating in the same conditions of temperature,

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$FeCl_3$ concentration and particle size is shown in Fig.1.

It can be seen from Fig.1, that the leaching rate of sphalerite with microwave heating is much faster than that with convenional heating. Leaching 30 min, the leaching rate of sphalerite with microwave heating reaches 59.3%, whereas that with conventional heating only reaches 28.4%.

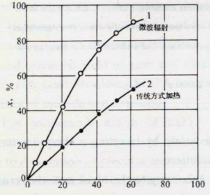

Fig.1 Comparision of microwave heating (1) and conventional heating (2)

T: 368K; $FeCl_3$: 1.0 M; partical size: −98+76 μm

Obviously, the difference between the two methods is significant and the results provide convincing advantages of the above microwave at work.

3.2 *Effect of Temperature*

The leaching rate of sphalerite vs leaching time and the temperature of solution in microwave field are shown in Curve 1 of Fig.2 and Fig.3 respectively, and the temperature of solution vs leaching time is shown in curve 2 of Fig.2.

As shown in Fig.2 and Fig.3, with microwave heating, the temperature of solution rises fast and the leaching rate of sphalerite increases quickly. The leaching process in the microwave field is in a nonisothermal state below the boiling point of the solution.

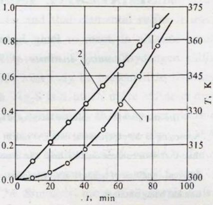

Fig.2 The leaching rate of sphalerite (*x*) and the temperature of solution (*T*) vs leaching time (t)

$FeCl_3$: 1.0 M; HCl: 0.1 M; particle size: −98+76μm

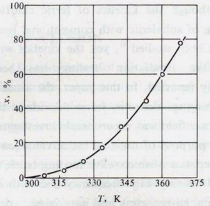

Fig.3 The leaching rate of sphalerite (*x*, %) vs temperature(*T*)

$FeCl_3$: 1.0 M; HCl: 0.1 M; particle size: −98+76μm

3.3 *Derivation of Mathematical Model of Leaching Kinetics*

The microwave heating Charactertistics are as follows:

(1) As the electromagnetic fields rapidly change direction, polar molecles attempt to

oscillate at the same rate and this molecular agitation not only generates heat but also accelerates the leaching.

(2) Microwave heating is able to supply the heat to the interior of a pellet. It would solve the problem of " cold centers" with conventional heating[5].

(3) Microwave heating would result in the rapture of the pellet, thus exposing a fresh surface to the reagent contact[6].

According to the microwave heating characteristics, the leaching of sphalerite could be considered as a chemical reaction and its rate (V) can be expressed as

$$V = -\frac{dW}{dt} = \frac{d(4\pi r^3 \rho / 3)}{dt} \quad (1)$$

where W–mass of pellet;

r–nucle radius before reaction;

ρ–density

$$V = kC^n \quad (2)$$

$$k = A \cdot e^{-E/RT} \quad (3)$$

where k–rate constsnt;

C–concentration;

n–recation stage;

A–freguency factor;

E–activation enery

from Eqs. (1) to (3), we obtain

$$-\frac{dr}{dt} = \frac{MC^n A}{\rho} e^{-\frac{E}{RT}} \quad (4)$$

for $-\frac{dr}{dT} \cdot \frac{dT}{dt} = -\frac{dr}{dt} = \frac{MC^n A}{\rho} e^{-\frac{E}{RT}}$ (5)

suppose $dT/dt = B$(according to curve 2 in Fig.2, $B = 0.837,1$)

$$-dr = \frac{MC^n A}{B\rho} e^{-\frac{E}{RT}} dT \quad (6)$$

Integrating over the intervals $[r_0, r]$, $[T_0, T]$, and putting $x = 1-(r/r_0)^3$ into (6), we obtain

$$1-(1-x)^{\frac{1}{3}} = \frac{MC^n AE}{BR\rho} P(\theta) \quad (7)$$

Where $P(\theta) = (e^\theta / \theta_2) \cdot (1+2! \ / \theta+3! \ / \theta^2+ / \cdots)$ and $\theta = -E/RT$. The kinetics model of sphalerite leaching is found by using two-terms of $P(\theta)$ and then taking the natural logarithm of Eq. (7)

$$\ln\left[\frac{1-(1-x)^{\frac{1}{3}}}{T^2}\right] = \ln\left[\frac{MC^n AR}{BE\rho}\right] \times \left[(1-\frac{2RT}{E})\right] - \frac{E}{RT} \quad (8)$$

From the relationship of $\ln\left[\frac{1-(1-x)^{\frac{1}{3}}}{T^2}\right]$ and $\frac{1}{T}$ (see Fig.4)[7], we obtain

$$\ln\left[\frac{1-(1-x)^{\frac{1}{3}}}{T^2}\right] = 4.186,5 - \frac{6,186.847,0}{T} \quad (9)$$

Where the relative coefficient is 0.997,3, $E = 51.41\text{kJ}/\text{mol}$, and $A = 1.52 \times 10^4$.

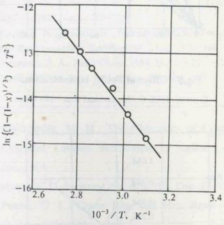

Fig.4 Plot of ln $\{[1-(1-x)1/3] / T^2\}$ vs 1 / T

3.4 *Effect of* $FeCl_3$ *Concentration.*

Fig.5 shows the leaching rate curve of various initial $FeCl_3$ concentrations, from which we find the leaching rate increaces with $FeCl_3$concentration. By plotting the data in the form $1-(1-x)^{1/3}$ vs t (see Fig.6), all the lines pass through the origin and the experimental rate constants are $8.775,5\times10^{-3}$, $5.429,9\times10^{-3}$, $3.900,6\times10^{-3}$, $2.875,6\times10^{-3}$ in 0.2, 0.3, 0.5, 1.0 M $FeCl_3$ and the relative coefficients are 0.999,1, 0.999,4, 0.997,8, 0.999,5 respectively. $\ln k$ vs $\ln M_{FeCl_3}$ are made as shown in Fig.7 and a reaction order of 0.69 is obtained; thus the relative coefficient is 0.999,7.

3.5 *Effect of Particle Size*

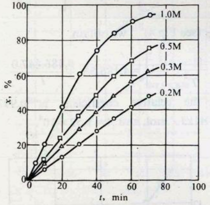

Fig.5 Effect of $FeCl_3$ concentration.

T: 368K; HCl: O.1M; partical size: −98+76μm

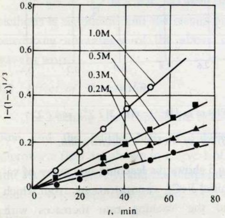

Fig.6 Plot of $1-(1-x)^{1/3}$ vs t in different $FeCl_3$ concentration

T: 368K; HCl: 0.1M; partical size: −98+76μm

As shown in Fig.8, a smaller particle size results in a faster leaching rate and date are found to agree with chemical reaction model (Fig.9). Plotting k vs $1/r_0$ we obtain Fig.10 which yields the linear relationship between them. A further results confirms that the leaching reaction is controlled by the chemical reaction.

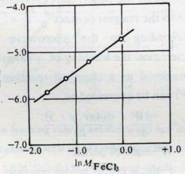

Fig.7 Plot of $\ln k$ vs $\ln M_{FeCl_3}$

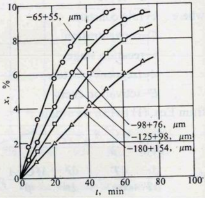

Fig.8 Effect of particle size

T: 368K; $FeCl_3$: 1.0 M; HCl: 0.1 M

4 CONCLUSION

(1) From the experiments, a generalized rate equation based on the chemical reaction control is derived as

$$\Phi = 1.52 \times 10^4 C_{FeCl_3}^{0.69} r_0^{-1} e^{-\frac{5.14 \times 10^4}{RT}} \cdot t$$

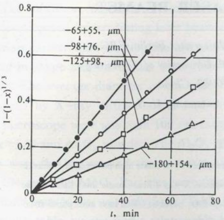

Fig.9 Relation between $1-(1-x)^{1/3}$ and t in different particle size

T: 368 K; $FeCl_3$: 1.0 M; HCl: 0.1 M

(2) The leaching rate of sphalerite with microwave heating is faster than that with conventional heating. Microwave heating can accelerate the leaching process and will be applied potentially to hydrometallurgy.

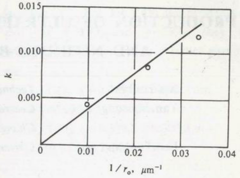

Fig.10 Relation of k and $1/r_0$

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study. This potential technique for processing Au–Cu sulfide concentrate, in the other hand, has some trouble in subsequent treatments for the great high levels of copper and other base metals in pregnant liquors due to addition of ammonia and EDTA.

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