



# Experiment of Gold and Silver Extraction from Cyanide Tailings by Melting Chlorination

Sun Yanwen, Yuan Chaoxin, Guo Chihao, Li Dajiang, Li Yibin, Mu Liangzhao

BGRIMM Technology Group, Beijing, China

## Email address:

maccosun@126.com (Sun Yanwen)

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**Abstract:** Cyanide tailings produced in gold smelting process contain a large number of heavy metals and cyanides, which are more and more harmful to the environment. In order to reduce environmental pollution, valuable metals from cyanide tailings are recovered. The amount of calcium chloride, chlorination time, the way of adding calcium chloride and other factors on the influence of gold and silver extraction by chlorination were studied by using the raw material of cyanide tailings with melting chlorination process in this paper, and how to reduce the melting chlorination temperature was explored, and a comprehensive experiment was carried out under the best conditions. The results showed that when the chlorination temperature is 1500°C, the chlorination time is 1 h, and the addition amount of  $\text{CaCl}_2$  is 7%, the volatilization rate of gold is 85.38%, the content of gold in slag is 1.83 g/t, the volatilization rate of silver is 77.36%, and the content of silver in slag is 4.12 g/t; when the chlorination temperature is 1500°C, 7%  $\text{CaCl}_2$  is added, and the chlorination time is 15 min, the volatilization rate of gold is 87.78%, the content of gold in slag is 1.23 g/t, the volatilization rate of silver is 59.40%, and the content of silver in slag is 7.39 g/t; the addition of 5%  $\text{CaO}$  can change the slag type, reduce the chlorination temperature by 50~100°C, increase the volatilization rate of gold and silver slightly, and decrease the content of gold and silver in slag; when  $\text{CaCl}_2$  is added in five times, the volatilization rate of gold increases to 95.53%, the content of gold in slag decreases to 0.56g/t, the volatilization rate of silver increases to 77.80%, and the content of silver in slag decreases to 4.04 g/t; 7%  $\text{CaCl}_2$  was added in five times, and the melting chlorination time was 15 min. the amount of  $\text{CaO}$  was 5%, and the melting chlorination temperature was 1450°C, the gold volatilization rate is 95.69%, and the gold content of slag is 0.54 g/t, the silver volatilization rate is 77.06% and the silver content of slag is 4.20 g/t.

**Keywords:** Cyanide Tailings, Melting Chlorination, Calcium Chloride, Calcium Oxide, Volatile Rate

## 1. Introduction

Cyanide tailings are a kind of waste residue of gold cyanidation smelting, which contains a large number of heavy metals [1] and cyanide. The accumulation of cyanide tailings is more and more harmful to environment. Now it is necessary to develop a gold extraction technology which can efficiently recover valuable metals from cyanide tailings, reduce environmental pollution and realize integrated recycling of resources. There are many researches [2-5] on how to recover gold from cyanide tailings. In recent years, chloridizing roasting process has been mainly used to treat cyanide tailings [6-15]. On the basis of photosynthetic method, BGRIMM Technology Group (hereinafter referred to as "BGRIMM") has developed chlorination roasting volatilization process to

recover valuable elements such as gold and silver from cyanide tailings. The process has been successfully applied in many smelters in china, with the abilities to efficiently recover gold and integrally recover other valuable elements. Chloridizing roasting process is suitable for tailings containing high percentage gold and silver, and it needs to consume a lot of energy. Now BGRIMM has further developed a new generation of chlorination volatilization process for gold extraction based on the existing chlorination roasting process. It is a process for integrated recycling of gold, silver and other valuable metals from cyanide tailings by short process molten salt chlorination under high temperature. The process has the characteristics of high volatile rate, high metal

recovery rate, small amount of flue gas and without secondary hazardous waste tailings. It can effectively deal with cyanide tailings and realize gold extraction without cyanide.

## 2. Experiment

### 2.1. Experiment Material

The raw material is cyanide tailings (hereinafter referred to

**Table 1.** Chemical composition of cyanide tailings.

composition	Au <sup>1)</sup>	Ag <sup>1)</sup>	Cu	Pb	Zn	TFe	Fe <sup>2+</sup>	CaO	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	As	S	C
Content (%)	12.52	18.2	0.23	0.26	0.36	31.38	0.70	1.75	0.75	15.75	30.15	1.39	1.14	0.41

Note: 1) unit is g/t

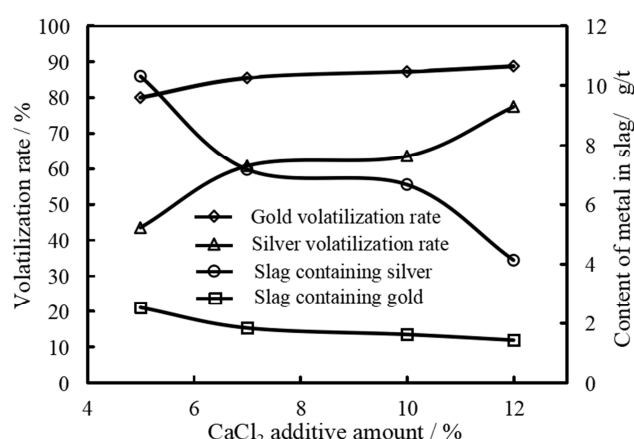
### 2.2. Experiment

Combined phase diagram corresponding to the tailings' composition and the gray cone method, the melting point of the tailings used in the experiment was 1434°C. Firstly, crucible with 100 g tailings was put into muffle furnace. Raised the muffle furnace temperature to 1500°C and kept the temperature for 0.5 h to make the tailings in molten state. Then, calcium chloride was added to the molten tailings, put them into muffle furnace for molten chlorination experiment after full stirring. Finally, the gold and silver contents in the tailings were analyzed after chlorinated, air-cooled, vibrational milled and sampled.

## 3 Results and Discussion

### 3.1. Effect of CaCl<sub>2</sub> Addition Amount on Gold Extraction

When the melting chlorination temperature of cyanidation tailings was 1500°C and the chlorination time was 1.0 h, the effect of CaCl<sub>2</sub> addition amount on the volatile rate of gold and silver in the tailings is shown in Figure 1.



**Figure 1.** The effect of CaCl<sub>2</sub> addition amount on gold and silver volatile rate.

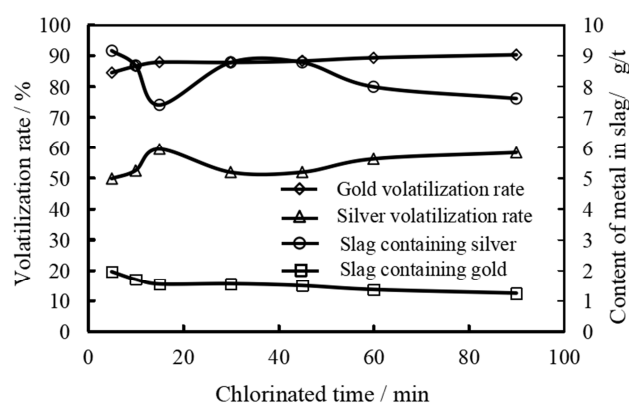
Figure 1 shows that the addition amount of calcium chloride has a significant effect on the volatile rate of gold and silver. When the addition of CaCl<sub>2</sub> increased from 5% to 7%, the volatile rate of gold increased from 79.87% to 85.38%, and the

as "tailings") with fine particle size ( $-0.074\text{ mm} > 95\%$ ) provided by a company, and the main ingredients are shown in Table 1. Due to the high content of gold and silver, the raw material has high recovery value. The tailings were used for experiment after drying, mixing and dividing. The iron in the raw material mainly exists in trivalent form, and the contents of copper, lead and zinc are not high, so this paper focuses on the volatile extraction of gold and silver from tailings.

gold content in tailing was 1.83 g/t. After that, the gold volatile rate increased a little with the increase of CaCl<sub>2</sub>. The volatile rate of gold only increased by 3% when the addition of calcium chloride increased by 5%, and the gold content in tailing only decreased by 0.4 g/t to 1.42 g/t. The results show that the 7% addition of CaCl<sub>2</sub> can meet the experiment conditions. The silver volatile rate increased significantly with the increase of calcium chloride addition. When the addition amount of CaCl<sub>2</sub> increased from 5% to 12%, the silver volatile rate increased from 43.41% to 77.36%, and the silver content in tailing was 4.12 g/t with good effect.

### 3.2. Effect of Chlorination Time on Gold Extraction

Experiment conditions: the melting chlorination temperature of tailings was 1500°C, the addition of CaCl<sub>2</sub> was 7% in the molten state, and the stir was thorough. On this condition, the effect of chlorination time on the volatile rate of gold and silver in tailings is shown in Figure 2.



**Figure 2.** The effect of chlorination time on gold and silver volatile rate.

The results show that the gold volatile rate increased markedly firstly and then increased gently with the increase of chlorination time. The gold volatile rate increased by 3.36% from 5 min to 15 min. The volatile rate was 87.78% at 15 min and 90.18% at 90 min. At 15 min, the gold content in the tailing was high, which was 1.23 g/t. Keep increasing the melting chlorination time has little effect on reducing the gold content in tailing. The silver volatilization increased when chlorination time was in the range of 5 min to 15 min, the

maximum volatile rate was 59.40% and the silver content in tailing was 7.39 g/t. The volatile rate of silver fluctuated slightly after 15 min, ranging from 51.81% to 59.40%. Above analysis indicates the best melting chlorination time is 15 min.

### 3.3. Research on Reducing Melting Temperature

The complete melting temperature of cyanide tailings is 1500 °C under the laboratory conditions. The temperature and energy consumption are both high. The melting point will reduce by changing the tailing composition. The main compositions of cyanide tailings are iron, silicon, calcium and aluminum. Divalent iron only accounts for 0.7% of the total iron, the iron mainly exists in the form of trivalent iron. The

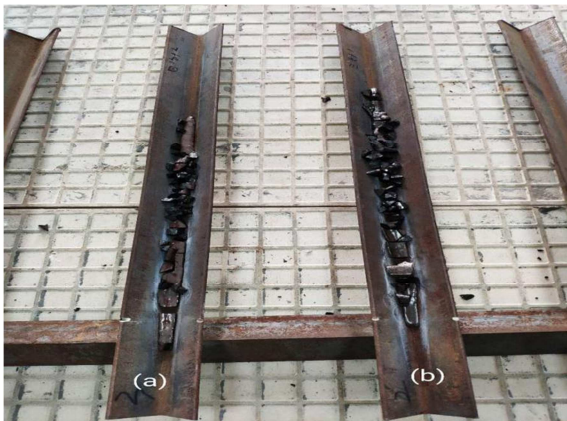
percentage of alumina is up to 15.72%, meanwhile, the percentage of CaO is only 1.75%. These factors lead to high melting temperature. Based on the phase diagram of Fe-Si-Ca-Al, it is decided to reduce the melting point by adding CaO.

Experiment conditions: first of all, one sample added 5% CaO and the other did not. 7%  $\text{CaCl}_2$  was added to samples in the molten state and stirred thoroughly. Then, put them into muffle furnace quickly for melting chlorination for 15 min. Lastly, the gold and silver contents in the tailings were analyzed after chlorinated, air-cooled, vibrational milled and sampled. The experiment phenomenon is shown in Figure 3, and the results are shown in Table 2.

**Table 2.** Effects of adding CaO on the volatile rate of gold and silver.

Experiment condition	gold content in the tailing (g/t)	gold volatile rate (%)	silver content in the tailing (g/t)	silver volatile rate (%)
With CaO	1.34	89.30	73.08	4.9
Without CaO	1.52	87.86	64.84	6.4

Figure 3 is the cooling diagram of cyanide tailings cinder, in which (a) is without CaO and (b) is added CaO. The results show that the addition of CaO can reduce the melting temperature by 50° C ~ 100 °C. It can be seen from the experiment phenomenon that the fluidity of adding CaO is better than without CaO. The effect of CaO addition on the volatile rate of gold and silver is shown in Table 2.



**Figure 3.** Schematic diagram of cinder fluidity.

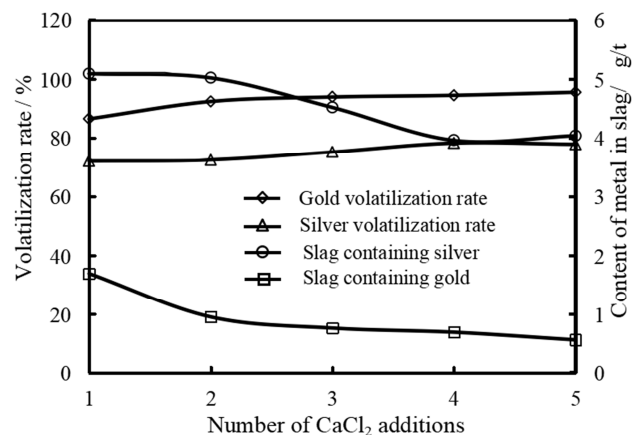
Table 2 shows that the addition of CaO can reduce the contents of gold and silver in the tailing. The addition of CaO increased the tailing mass by 1.05 times, however, the gold content in tailing was still lower than that without CaO. The volatile rate of gold was slightly increased by 1.44%, but the silver volatile rate increased by 8.24%. In addition, the addition of CaO can reduce the melting point and improve the fluidity of the molten melt at 1450 °C, which is beneficial for the melting chlorination experiment.

### 3.4. Effect of Adding $\text{CaCl}_2$ in Batches on Gold Extraction

Experiment conditions: the cyanide tailings were melted at 1450 °C after adding 5% CaO. In the molten state, 7%  $\text{CaCl}_2$  was added in batches and stirred fully with 15 min intervals. The effect of adding calcium chloride in batches on gold and

silver volatile rate are presented in Figure 4.

It can be found from Figure 4 that the volatile rate of gold increased by 10.03% from 85.50% to 95.53% when the adding times of  $\text{CaCl}_2$  increased from one time to five times. And the gold content in tailing was reduced from 1.69 g/t to 0.56 g/t, which realized the experiment purpose. The silver volatile rate also increased by 5.77%, from 72.03% to 77.80%. The silver content in tailing decreased to 4.04 g/t, and the volatilization effect was good. These illustrate that adding calcium chloride in batches has great effect on the volatile rate of gold and silver.



**Figure 4.** The effect of adding calcium chloride in batches on gold and silver volatile rate.

### 3.5. Comprehensive-factor Experiment

According to 2.1 ~ 2.4, the best experiment conditions were as follows: 100 g cyanide tailings was weighed, the addition amount of CaO was 5%, the melting chlorination temperature was 1450°C. And the addition amount of  $\text{CaCl}_2$  was 7%, which was added in five times with 15 minutes interval. The mixture was also thorough. Chlorination was performed for 15 minutes, followed by air-cooled and vibrational milled, sampled for analysis was the last step. The results are shown in Table 3.

**Table 3.** Contents and volatile rates of gold and silver in tailing under comprehensive-factor experiment.

Number of experiments	Composition of tailing, (g/t)		volatile rate, (%)	
	Au	Ag	Au	Ag
1	0.56	4.04	95.53	78.02
2	0.52	4.35	95.85	76.10
mean value	0.54	4.20	95.69	77.06

The comprehensive-factor experiments show that the gold volatile rate was 95.69%, the content of gold in tailing was 0.54 g/t, and the volatile rate of silver was 77.06%, the silver content of silver in tailing was 4.20 g/t. The experiments achieved the expected goal.

## 4. Conclusion

The volatilization of gold and silver in cyanide tailings was studied by melting chlorination in this work.

- (1) When the chlorination temperature is 1500°C, the chlorination time is 1 h, and the addition amount of CaCl<sub>2</sub> is 7%, the volatilization rate of gold is 85.38%, the content of gold in slag is 1.83 g/t, the volatilization rate of silver is 77.36%, and the content of silver in slag is 4.12 g/t;
- (2) When the chlorination temperature is 1500°C, 7% CaCl<sub>2</sub> is added, and the chlorination time is 15 min, the volatilization rate of gold is 87.78%, the content of gold in slag is 1.23 g/t, the volatilization rate of silver is 59.40%, and the content of silver in slag is 7.39 g/t;
- (3) The addition of 5% CaO can change the slag type, reduce the chlorination temperature by 50~100°C, increase the volatilization rate of gold and silver slightly, and decrease the content of gold and silver in slag; when CaCl<sub>2</sub> is added in five times, the volatilization rate of gold increases to 95.53%, the content of gold in slag decreases to 0.56 g/t, the volatilization rate of silver increases to 77.80%, and the content of silver in slag decreases to 4.04 g/t;
- (4) 7% CaCl<sub>2</sub> was added in five times, and the melting chlorination time was 15 min. the amount of CaO was 5%, and the melting chlorination temperature was 1450 °C, the gold volatilization rate is 95.69%, and the gold content of slag is 0.54 g/t, the silver volatilization rate is 77.06% and the silver content of slag is 4.20 g/t.

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