

Precious metal content in copper concentrate and slag

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Abstract

In recent years, especially in the emerging countries, the demand for precious metals like gold and silver has increased with the significant growth of economy. Chalcopyrite is the world's most important ore of copper for at least five thousand years. During the extraction of copper, Chalcopyrite is concentrated using the froth flotation process. The product from this froth flotation process is known as copper concentrate. Waste matter separated from copper during the smelting or refining of copper ore is known as slag. In the present work, the precious metals like gold and silver content in concentrate and slag are analyzed. Copper concentrate contains less than 2ppm of gold and less than 120ppm of silver. Slag contains less than 0.2ppm of gold and less than 2ppm of silver. The amount of gold and silver in slag are very less when compare their values in concentrate. The presence of gold and silver in the slag suggests that this precious metals escape to slag during the extraction of copper. This problem requires further research.

Keywords: *Chalcopyrite, extraction, gold, silver*

1. Introduction

Copper is the world's oldest metal, with its first use dating back 10,000 years. Prehistoric societies used copper in piping, utensils, surgical instruments, tools, weapons and ornaments. Today, copper is used in construction, transportation and telecommunication technologies. Copper is the key element in conducting electricity and is used in almost every aspect of our lives, whether it is driving, watching television, making a phone call or turning on a light. It fuels the development of our communities, the growth of our economies and the improvement of our quality of life. In an "electric" economy, copper has become indispensable [1, 2].

Chalcopyrite is a brass-yellow mineral with a chemical composition of CuFeS_2 . It occurs in most sulfide mineral deposits throughout the world and has been the most important ore of copper for thousands of years. The most apparent physical properties of chalcopyrite are its brassy yellow color, metallic luster, and high specific gravity. These give it a similar appearance to pyrite and gold [3, 4].

The name "fool's gold" is most often associated with pyrite because it is more common and more often confused with gold. Chalcopyrite is also confused with gold, so the name "fool's gold" is also applied and appropriate.

Precious metals are elemental metals that have high economic value. Gold is the easiest precious metal to recognize because of its unique yellow color. Gold is popular because of its color, malleability, and conductivity. Silver is a popular precious metal for jewelry, but its value extends well beyond beauty. It has the highest electrical and thermal conductivity of all the elements, plus it has the lowest contact resistance [5, 6].

In the extraction of copper, most high grade copper sulfide ores are concentrated using the froth flotation process. The product from this froth flotation process is known as copper concentrate. When the froth is dried it is known as copper concentrate. Waste matter separated from metals during the smelting or refining of ore is known as slag [7 - 10].

In the present work, the precious metals like gold and silver content in concentrate and slag are analyzed during the extraction of copper and their values are presented and discussed.

2. Experimental Methodology

2.1. Chemicals required

Lead flux No-1, Lead flux No-2, cover flux, potassium nitrate, silver foil, AR grade nitric acid, AR grade hydrochloric acid.

2.2. Determination of gold and silver in copper concentrate

2.2.1. Assay Sample Preparation

Required numbers of fusion crucible was taken and it is cleaned inside and outside by paint brush. All the cleaned crucibles were arranged near the rough balance for flux weighing. 200g of flux-I was weighed in all crucible without any spillage. Based on the trial fusion result, required quantity of potassium nitrate was added into the crucible. 15g of copper concentrate sample was weighed and carefully transferred it into the same crucible. The identification on the crucible was made by crayons. All the contents were mixed thoroughly in the crucible with big spatula. Required volume of 1000 ppm silver solution was added if necessary (If, Au:Ag does not exist in the ratio of 1:3), the contents inside the crucible was covered with 20g of cover flux.

2.2.2. Fusion

The fusion crucible was loaded into the crucible fusion furnace carefully at 1060°C. The furnace was allowed to reach the process temperature 1060°C. After 1 hour 15 minutes, a 50g flux-II packet was added directly into the crucible inside the furnace. Again the furnace temperature was maintained at 1060°C for 1 hour. The crucible was removed from the furnace, and the molten liquid was poured into the cast moulds, the exhaust was switched on before pouring the molten mass. It was cooled to room temperature & the lead button was separated from the slag using the hammer. The correct identification was made on the lead button, by the reference to the crucible.

2.2.3. Cupellation

The Cupellation Furnace temperature was set at 950°C, the empty and clean cupels were loaded inside the furnace for pre-heating, and the crucible was sustained for 20-30 min. Then the lead button was put serially over the cupels arranged in order. After reaching 950°C, the blower was switched on and the knob position was set at 0.5.

Constant and frequent look for the end of the cupellation process was done, as soon as cupellation was over the cupels from the furnace were removed immediately. It was cooled to room temperature. The correct identification on the cupel was written by the reference of the lead button. Prill from the cupel was removed carefully by knife and forceps. The prill was kept in a clean porcelain crucible. The proper identification on the porcelain crucible was made by the reference of the cupel.

2.2.4. Parting

The cupel dust on the prill was cleaned by using knife and forceps very carefully. The cleaned prill was put again into the same porcelain crucible. The Total Precious Metal prill (TPM bead) was weighed using the micro balance. The TPM bead was flattened by hammer and anvil and the TPM bead was put into the same porcelain crucible, 15ml of 15% HNO₃ was added into the crucible. It was kept on the hot plate for 30-45 min at the temperature of 60°C (till the volume reduces to half). The porcelain crucible was removed from the hot plate, and the solution was discarded and washed with double distilled water thrice. 15ml of 50% HNO₃ was added into the crucible, it was kept on the hot plate at 60°C for 30-45 min (volume will reduce to half). The crucible was removed from the hot plate, when the volume was reduced to half; the solution was discarded and washed with double distilled water minimum 5 times. The crucible was dried on the hot plate for 15 min, The prill was annealed in muffle furnace at 650°C for 5 min, it was cooled to room temperature. The gold prill was weighed using microbalance.

2.2.5. Determination of Cupellation Loss Factor

About 0.5-1.0 mg of pure Ag was weighed into 65g of lead foil. It was wrapped properly and maintained the identification. The lead foil was kept into the preheated cupel inside the cupel furnace. The blower was started when the temperature of the furnace reaches 940°C. The cupel was taken out as soon as the cupellation over; it was cooled to room temperature. The Ag bead was removed from the cupels and it was cleaned and weighed. Cupellation loss factor was calculated by using the following equation.

$$CLF = \frac{\text{Wt. of Ag before cupellation}}{\text{Wt. of Ag after cupellation}}$$

Mean of all the CLF values at different position in the cupellation furnace were found by the following equation.

$$CLF \text{ Mean} = \frac{CLF_1 + CLF_2 + CLF_3 + \dots + CLF_n}{n}$$

1,2,3..... n represent the position of the cupels inside the cupellation furnace.

The exact weight of gold was calculated by using the following equation

$$Au \text{ (ppm)} = \frac{\text{Wt. of TPM (mg)} - \text{Wt. of gold (mg)} \times CLF \times 1000}{\text{Wt. of sample taken for analysis}}$$

2.3. Determination of gold and silver in granulated slag

2.3.1. Sample Preparation

Required numbers of fusion crucibles were taken, it was cleaned inside and outside by paint brush. All the cleaned crucibles were arranged near the rough balance for flux weighing. 200g of flux-I was weighed in all crucibles without any spillage. 3g of starch was added in to the crucible. 25 of Granulated slag was weighed and carefully transferred into the same crucible and ensured that there should not be any pinch of sample on the watch glass. 0.5-1 mg of silver foil was added into the crucible. The identification on the crucible was written by crayons. All the contents were mixed thoroughly in the crucible with big spatula. The content was covered inside the crucible with 30g of cover flux.

2.3.2. Fusion

The fusion crucible was loaded into the crucible fusion furnace carefully at 1060°C. The furnace was allowed to reach the process temperature to 1060°C then let it be the temperature of the furnace at 1060°C for 1 hour 45 minutes. Then 50g flux-II packets were added directly into the crucible inside the furnace. Again the furnace temperature was maintained at 1060°C for 1 hour. The crucible was removed from the furnace and the molten liquid was poured into the cast moulds, the exhaust was switched on before pouring the molten mass. It was cooled to room temperature and the lead button was separated from the slag using the hammer. The correct identification was made on the lead button by the reference to the crucible.

2.3.3. Cupellation

The cupellation furnace temperature was set at 950°C, the empty and clean cupels were loaded inside the furnace for pre-heating and sustained the crucible for 20-30 min. Then the lead button was put serially over the cupels arranged in order. After reaching temperature at 950°C the blower was switched on and the knob was set position at 0.5. Constant and frequent look for the end of the cupellation process was kept on; as soon as cupellation was over, the cupels were removed from the furnace immediately. It was cooled to room temperature. The correct identification was written on the cupel by the reference of the lead button. Carefully the prill was removed from the cupel by knife and forceps. The prill was kept in a clean porcelain crucible; the proper identification was made on the porcelain crucible by the reference of the cupel.

2.3.4. Parting

The cupel dust on the prill was cleaned by using knife and forceps very carefully. Again the cleaned prill was put into the same porcelain crucible. The Total precious metal prill (TPM bead) was weighed using the micro balance. The TPM bead was put into the 10ml standard measuring flask. 1.5ml of con HNO₃ was added and kept on hot plate. 3.5ml of con HCl was added and then DD water was added.

2.3.5. ICP analysis

The ICP instrument was calibrated using blank (DD water) and standard solutions of gold. The sample solutions were introduced to get the amount of gold present in the sample.

The amount of silver and gold were calculated by using the following equations

$$\text{Au (ppm)} = \frac{\text{Au (ICP Value)} \times 10}{\text{Weight of Sample taken for analysis}}$$

$$\text{Ag (ppm)} = \frac{(\text{TPM Wt (mg)} \times \text{CLF} - \text{Added Ag (mg)}) \times 1000}{\text{Weight of Sample taken for analysis}} - \text{Ag (ppm)}$$

3. Results and Discussion

3.1. Gold content in concentrate

Table 1. Gold content in concentrate

Sample	Gold (ppm)
1	0.8666
2	1.9555
3	0.4000
4	0.3330
5	0.9333

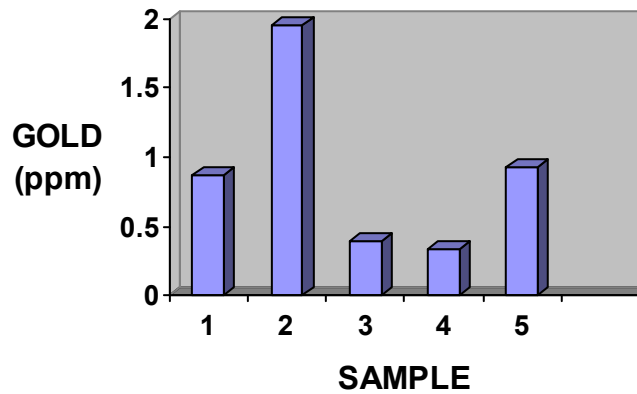


Figure 1. Gold content in concentrate

The amount of gold present in the copper concentrate is in the range of 0.3330 to 1.9555ppm. Copper concentrate contains less than 2ppm of gold.

3.2. Silver content in concentrate

Table 2. Silver content in concentrate

Sample	Silver (ppm)
1	110.9129
2	63.9714
3	66.3219
4	70.8617
5	110.4751

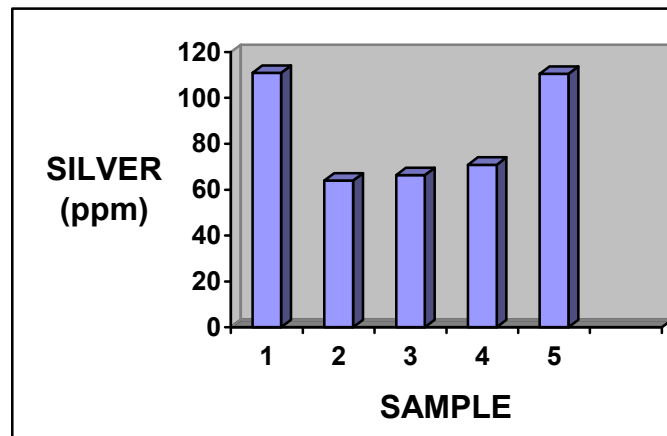


Figure 2. Silver content in concentrate

The amount of silver present in the copper concentrate is in the range of 63.9714 to 110.9129ppm. Copper concentrate contains less than 120ppm of silver. Depending on the amount of Gold and Silver in the Copper concentrate the cost of the Copper concentrate is fixed.

3.3. Gold content in slag

Table 3. Gold content in slag

Sample	Gold (ppm)
1	0.195
2	0.189
3	0.186
4	0.188
5	0.190

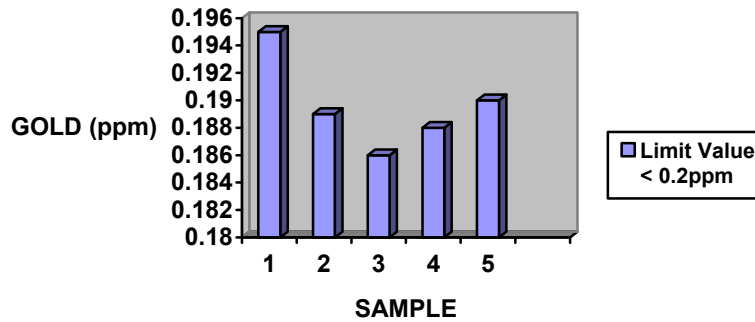


Figure 3. Gold content in slag

The amount of gold present in the slag is in the range of 0.186 to 0.195ppm. Slag contains less than 0.2ppm of gold.

3.4. Silver content in slag

Table 4. Silver content in slag

Sample	Silver (ppm)
1	1.31
2	1.34
3	1.14
4	1.28
5	1.75

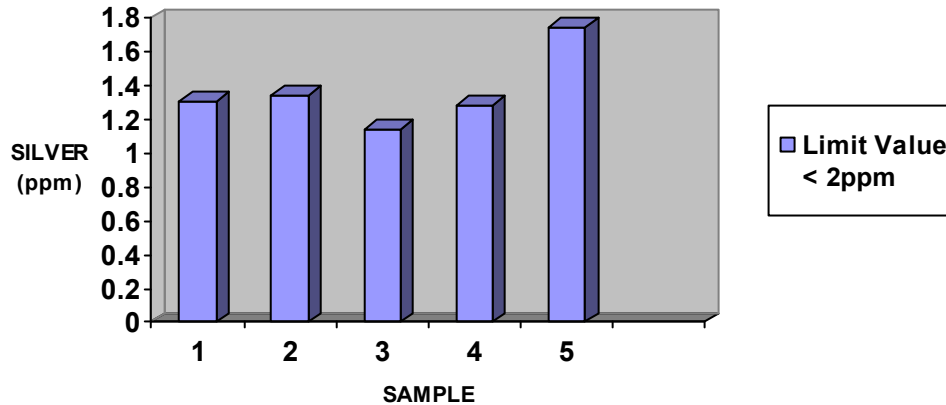


Figure 4. Silver content in slag

The amount of silver present in the slag is in the range of 1.14 to 1.75ppm. Slag contains less than 2ppm of silver. Their values in slag are very less when compare their values in concentrate. The presence of gold and silver in the slag suggests that this precious metals escape to slag during the extraction of copper. This problem requires further research.

4. Conclusion

The distribution of some precious metals like silver and gold in copper concentrate and slag was studied. Chalcopyrite ores contain significant amounts of silver and gold that the precious metal content more than pays the costs of mining. Slag contains small amount of gold and silver. Generally, trace precious metals remaining in waste slag generated from the refining process of copper are not recovered, due to a relatively high processing cost as well as various technical problems. Thus further research is required to reduce wastage of precious metals in the form of slag.

5. References

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