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A study of the chemical composition of copper concentrate and granulated slag

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Abstract

The smelting of copper concentrates with higher content of impurities leads to increase in their concentrations in the intermediate products such as matte and blister copper. This causes a serious problem in controlling the quality of the final product cathode copper. Therefore, a better understanding of quantity of impurities (iron, sulphur, silica and lime) in copper concentrate and their behavior in copper smelting systems could improve the efficiency of copper extraction. In this research work, the percentage of copper, lime and iron in copper concentrate and slag were determined by volumetry. Quantities of sulphur and silica in copper concentrate and granulated slag were calculated by gravimetry. The effect of iron, sulphur, silica, and lime content in concentrate in the extraction of copper are discussed.

Keywords: *Chalcopyrite, iron, silica, lime*

1. Introduction

Copper is a metallic element that is naturally present in many substances, including rocks and soil, selected plants and insects, snails, and even the human liver. Commercial sources of copper are found in deposits which formed under the earth's surface as the result of early volcanic disturbances. Primary ores, called sulfide ores, formed when molten solutions flowed into the earth's crust. Secondary ores, called oxide ores, were formed as weather and other natural forces altered ancient rocks. Both sulfide ores and oxide ores are mined and processed to extract copper metal [1-4]. Humans can have regular contact with copper and copper oxide through its many applications [5-8].

Chalcopyrite is a common mineral and is found in almost all sulfide deposits and is often disseminated through igneous rocks. As a copper ore, the yield of chalcopyrite is rather low, in terms of copper content. It is only 25%, compared to other copper minerals such as chalcocite, covellite, cuprite, or bornite which may contain 50% to 60% copper. However the great quantities and many localities make chalcopyrite the leading source of copper. From the Greek words chalkos, "copper" and pyrites, "strike fire"[9-10].

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 (which is between 20 and 40% copper) is

dried, it is known as copper concentrate. Stony waste material formed during the smelting or refining of metals by combining the flux with gangue, impurities in the metal, etc is known as slag [11-15].

We're in no danger of running out of copper. Known world-wide resources of this important and valuable metal are estimated at nearly 5.8 trillion pounds of which only about 0.7 trillion (12 percent) have been mined throughout history.

In the present work, the various impurities like iron, silica, sulphur and lime content in copper concentrate and slag are analyzed during the extraction of copper and their values are presented and discussed.

2. Experimental Methodology

2.1. Estimation of Copper

Copper content was determined by titration against standard sodium thiosulphate solution using starch as an indicator.

$$\text{Cu content in \% (W/W)} = \frac{\text{Titre value} \times \text{Copper equivalent of thio sulphate} \times 100}{\text{Weight of sample taken for the analysis}}$$

2.2. Estimation of Iron

Iron content was calculated by titration against standard potassium dichromate solution using diphenylamine as an indicator.

$$\text{Total Iron in \% (W/W)} = \frac{\text{Titre value} \times \text{Iron equivalent of dichromate} \times 100 \times 10}{\text{Weight of the sample taken for the analysis}}$$

2.3. Estimation of Sulphur

Sulphur content was calculated by gravimetric method using barium chloride as a precipitating agent.

$$\text{Sulphur in \%(W/W)} = \frac{\text{Weight of Barium sulphate precipitate} \times 10 \times 0.137339 \times 100}{\text{Weight of the sample taken for the analysis}}$$

2.4. Estimation of Lime

Lime content is determined by volumetric titration against standard potassium permanganate solution.

$$\text{Lime content in \% (w/w)} = \frac{\text{Titre value} \times \text{Lime equivalent of permanganate} \times 10 \times 100}{\text{Weight of the sample taken for the analysis}}$$

2.5. Estimation of silica

About 0.5g of the copper concentrate/ slag was weighed in a watch glass and it was transferred into a 250ml beaker completely using a brush. 10ml of concentrated nitric acid and 10ml of concentrated hydrochloric acid were added. A pinch of potassium chlorate was added. It was mixed well and heat to dryness on a hot plate. The solids were re-dissolved in hydrochloric acid. The solution was filtered using a Whatman 41 filter paper. After the completion of filtration and washing with distilled water, the residue was ignited in a Muffle furnace in a pre weighed platinum crucible (w_1). After complete ignition, it was cooled it in the desiccator. The crucible was weighed (W_1). 1 or 2 drops of concentrated sulphuric acid and 1 to 2 ml of concentrated hydrofluoric acid were added to the content. It was heated to dryness on a hot plate and further it was ignited it in the Muffle furnace. It was cooled to the room temperature and weighed (W_2).

$$\text{Silica content in \% (w/w)} = \frac{(W_1 - W_2) \times 100}{\text{Weight of Sample taken for the analysis}}$$

3. Results and Discussion

3.1. Determination of chemical composition in copper concentrate

3.1.1. Copper content in concentrate

Table 1. Copper content in concentrate

Sample	% of Copper
1	36.98
2	29.09
3	29.90
4	23.14
5	28.15

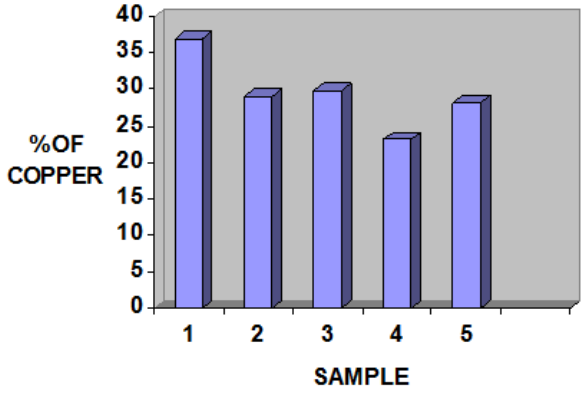

Figure 1. Copper content in concentrate

Percentage of copper present in the copper concentrate is in the range of 23.14 to 36.98 %. Thus, chalcopyrite is preferable to get large amount of copper at the end of the extraction.

3.1.2. Sulphur content in concentrate

Table 2. Sulphur content in concentrate

Sample	% of Sulphur
1	33.01
2	33.22
3	32.73
4	39.55
5	32.50

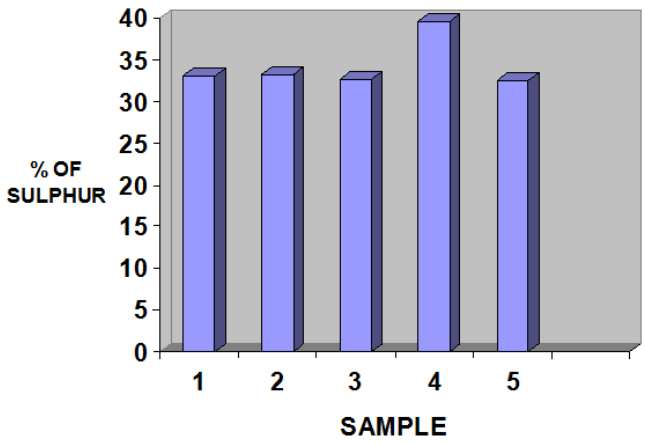

Figure 2. Sulphur content in concentrate

Percentage of sulphur in copper concentrate is in the range of 32.50 to 39.55%. During the extraction process, sulphur is converted into harmful SO_2. But this SO_2 is used to prepare useful H_2SO_4 and phosphoric acid.

3.1.3. Iron content in concentrate

Table 3. Iron content in concentrate

Sample	% of IRON
1	22.34
2	31.27
3	25.13
4	29.88
5	34.91

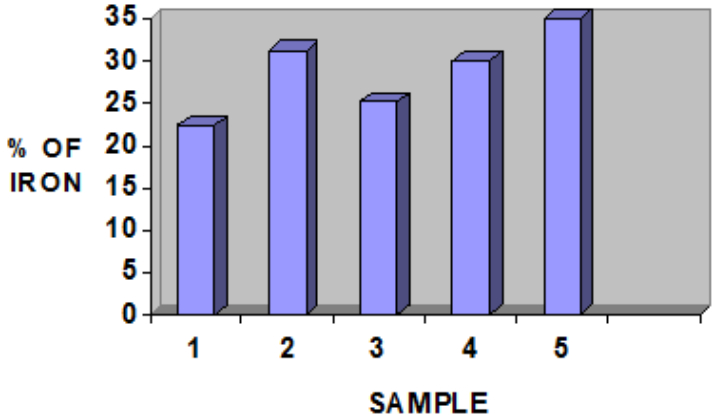

Figure 3. Iron content in concentrate

About 22.34 to 34.91 % of iron is present copper concentrate.

3.1.4. Silica content in concentrate

Table 4. Silica content in concentrate

Sample	% of Silica
1	4.56
2	3.26
3	7.72
4	1.86
5	2.24

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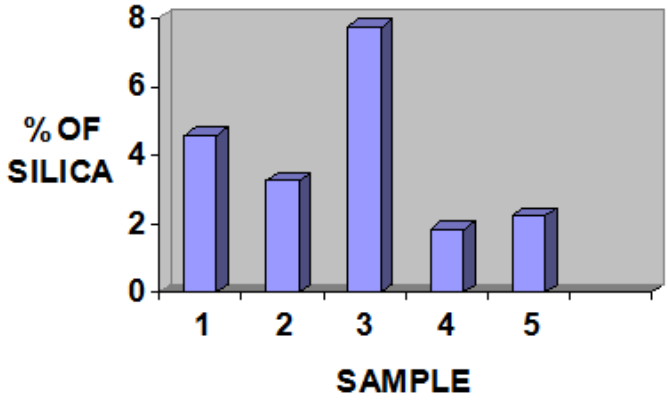

Figure 4. Silica content in concentrate

Percentage of silica in copper concentrate is in the range of 1.86 to 7.72%.

3.1.5. Lime content in concentrate

Table 5. Lime content in concentrate

Sample	% of Lime
1	0.09
2	0.05
3	0.51
4	0.12
5	0.18

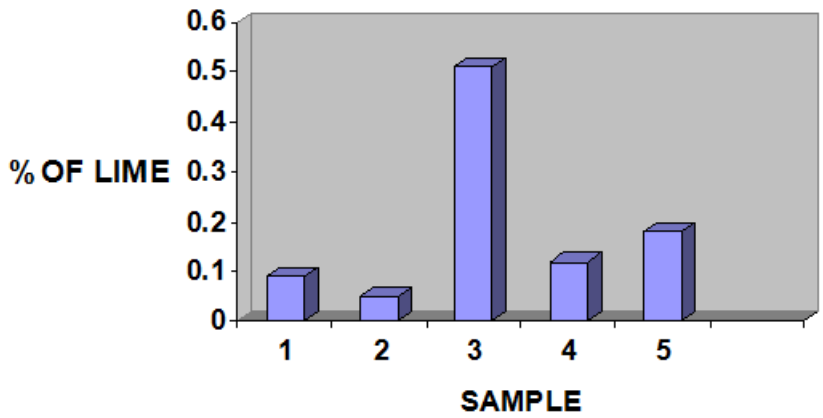

Figure 5. Lime content in concentrate

About 0.05 to 0.51 % of lime is present in copper concentrate.

The ratio of Iron/Silica = 1.2 is needed for proper extraction. Depending upon the ratio, silica should be added to remove FeO as $FeSiO_3$. So more amount of silica should be added for proper extraction. The ratio of Silica/Lime = 0.3 – 0.5 should be maintained to avoid the loss of copper as waste in slag. Hence from the results it can be easily concluded that these copper concentrates require certain amount of lime to avoid the loss of Copper.

3.2. Determination of chemical composition in granulated slag

3.2.1. Copper content in slag

Table 6. Copper content in slag

Sample	% of COPPER
1	0.60
2	0.64
3	0.52
4	0.62
5	0.59

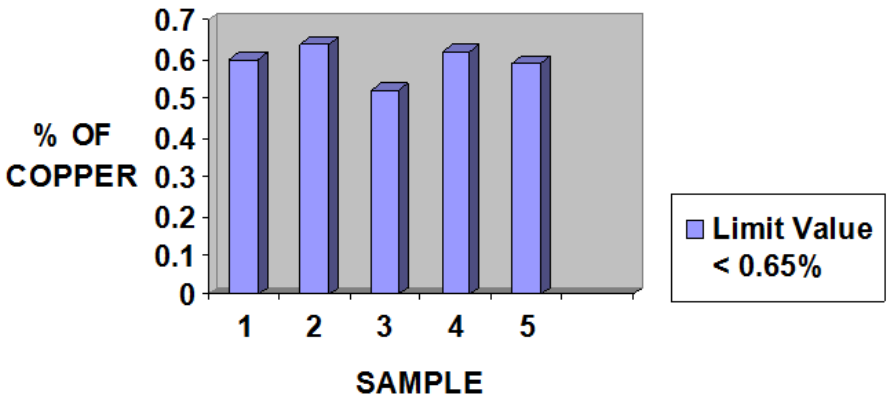

Figure 6. Copper content in slag

The percentage of copper in slag is in the range of 0.52 to 0.64. If the Silica/Lime ratio is not properly maintained during copper extraction, the values will be greater than the limit value.

3.2.2. Iron content in slag

Table 7. Iron content in slag

Sample	% of IRON
1	43.08
2	42.83
3	44.81
4	42.69
5	43.38

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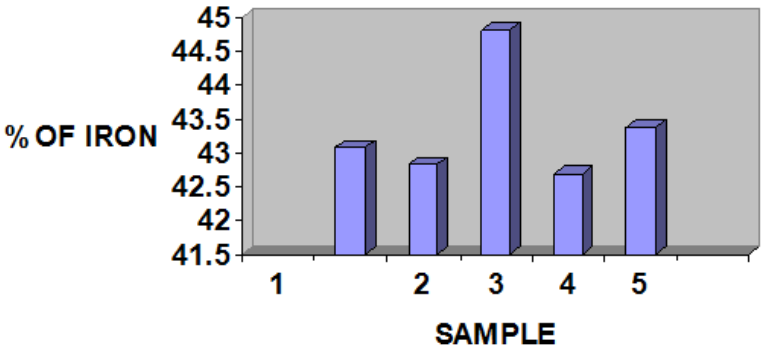

Figure 7. Iron content in slag

The percentage of iron present in slag is in the range of 42.69 to 44.81%.

3.2.3. Silica content in slag

Table 8. Silica content in slag

Sample	% of SILICA
1	34.67
2	33.87
3	32.63
4	34.07
5	34.52

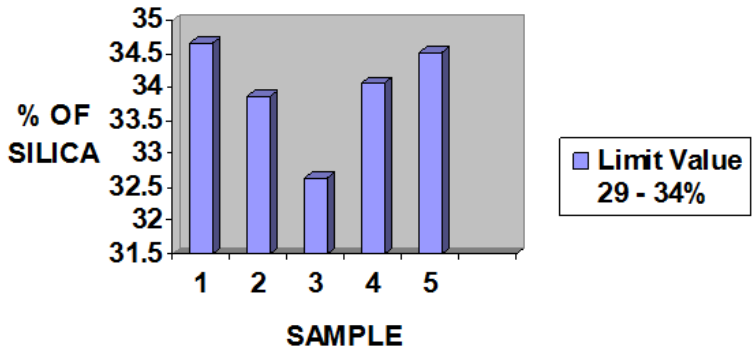

Figure 8. Silica content in slag

The percentage of silica present in slag is in the range of 32.63 to 34.67. The value of silica in slag will usually be greater than that in concentrate. This may be due to external addition of silica during the extraction.

3.2.4. Lime content in slag

Table 9. Lime content in slag

Sample	% of LIME
1	2.14
2	2.15
3	2.76
4	2.23
5	2.17

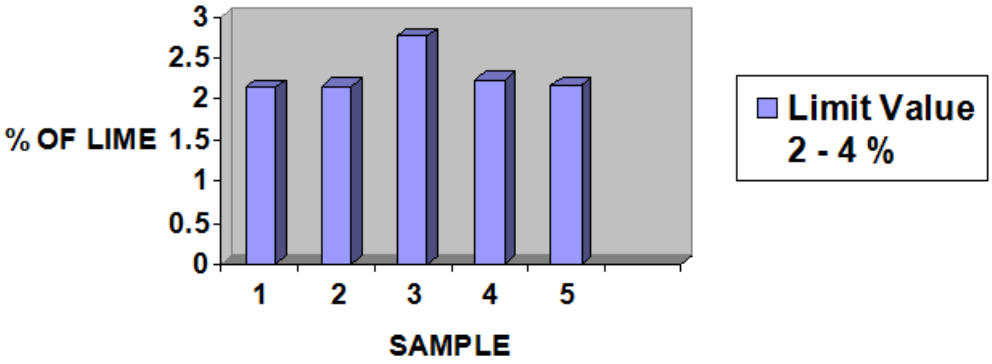

Figure 9. Lime content in slag

The percentage of lime present in the slag is in the range of 2.14 to 2.76. The values of percentage of Lime in slag will usually be greater than that in concentrate. This may be due to external addition of lime during the extraction.

4. Conclusion

Copper concentrate contains copper, iron, sulphur, silica and lime. So it is enough to add only less amount of silica and lime than the required amount to maintain iron/silica and silica/lime ratios during the extraction. During the extraction process sulphur is converted into harmful SO_2. The most harmful sulphur dioxide gases are converted into sulphuric acid and finally into phosphoric acid. So sulphur is not available in slag. Granulated slag produced during copper smelting is widely used for sand blasting, land filling and as an abrasive in the ship building industries. The slag excellently substitutes blue metal chips in road laying.

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