

An Investigation into the Effect of Temperature on the Leaching of Copper-Matte

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Abstract—A study was carried out to determine the influence of the temperature and the reaction involved on the leaching of copper-matte. Copper (Cu) bearing matte from Impala Refinery (Pty) Ltd was used in the investigation. The experiments were conducted in a leaching cell submerged in a water bath, with ammonia concentrations (leaching solution) of 3.0M, temperature of 50°C, 60°C and 70°C, pH of 11 and for a time period of 130 minutes. Leaching tests indicated that Cu recovery increased in the temperature range 50°C - 60°C, however at a temperature of 70°C Cu recovery decreases because of cementation process as nickel displace copper. The shrinking core model was used to determine if the leaching process was diffusion controlled, or chemical controlled, or even mixed controlled. It was found that the leaching process could not be determined using the shrinking core model due to the cementation process of Cu. It was concluded that an increase in temperature results in an increase in the Cu recovery however the temperature should not be too high as cementation process increase with increasing temperature.

Keywords—Cementation, diffusion controlled, Leaching, matte, recovery.

I. INTRODUCTION

THE extraction of copper metals from matte (mixture of metal sulphides and precious metals) has been a critical process in the refining of precious metals. Matte is produced from the smelting of sulphide ores to separate the valuable metals from the gangue (waste material). Base (copper) metals are normally recovered from the precious metals by leaching leaving behind a solid residue rich in precious metals and producing a base metal rich liquor.

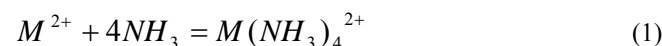
Leaching is the extraction of a soluble constituent from a solid by means of a solvent [1]. Generally the leaching process can be considered by the change of phase of solute as it dissolves in the solvent, diffusion of the solute through the solvent in the pores of the solute to the outside of the particles and the transfer of the solute from the solution in contact with the particles to the main bulk of the solution. An active chemical solution known as a lixiviant or leaching solution is brought into contact with the ore (or concentrate). The transfer of a metal from ore to lixiviant constitutes a transfer from a solid to a liquid phase. Because the dissolution is selective, most of the unwanted components in the ore are unaffected by the leaching process and remain in the solid state. Consequently, the metal is separated from them when the solids are separated from the solution after the leach process has been completed. The solution that is produced is termed a

pregnant solution or leach liquor. The solid product is termed the residue or tailings.

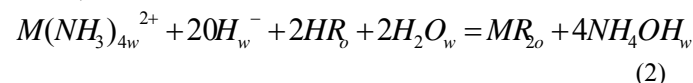
II. LEACHING AGENT

Ammonia as an effective leaching agent has been widely used in a number of Hydrometallurgical processes. The main advantage is that the basic leach solution alleviates corrosion problems encountered in the acid systems. Ammonia is also advantageous in that ammonia and ammonium ion constitute a pH buffer solution. However, it has the disadvantage of operating at relatively high temperature and pressure.

Extraction of copper using ammonia solutions proceeds in an analogous way as that of using acid solutions. However, it is necessary to consider metal complexing by ammonia molecules:



Hence, the extraction can be described as:



It is possible to extract out the copper metal almost completely at a single extraction stage when using an appropriate concentration of ammonia. A combination of ammonia and ammonium salt is known to be a powerful lixiviant used in hydrometallurgical processes [2]. Fig. 1 shows the X-ray diffraction pattern for matte before and after leaching at different times.

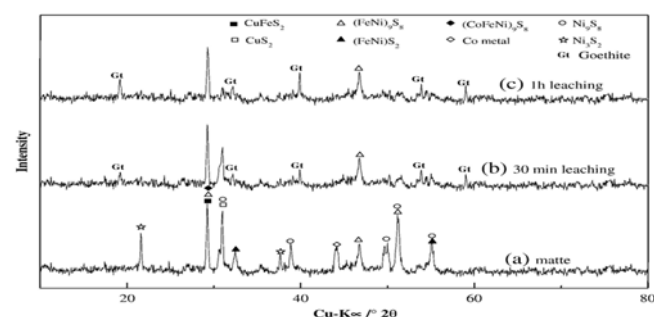


Fig. 1 X-ray diffraction pattern for matte, (a) before leaching, (b) and (c) after leaching at different times

Test work has been performed using atmospheric leaching by comparing the leaching efficiency of dilute sulphuric acid-oxygen system and ferrous solution-oxygen system as leaching agents (Makhubela, 2008). Leaching with acidified ferrous solution resulted in higher Cu recovery of 60% as

compared to dilute sulphuric acid 40%. However, more information is required in terms of understanding the mechanisms and kinetics of the process before a full-scale operation is designed.

III. MATERIALS AND METHODS

A. Material

The material used in this investigation was Cu matte from Impala Refinery. The chemical composition of the matte is shown in Table I and Fig. 2 below. The principal phases present in the matte were heazlewoodite (Ni_3S_2), chalcocite (Cu_2S), djurleite ($\text{Cu}_1.9\text{S}$) and nickel alloy. The leaching solution used was ammonium solution.

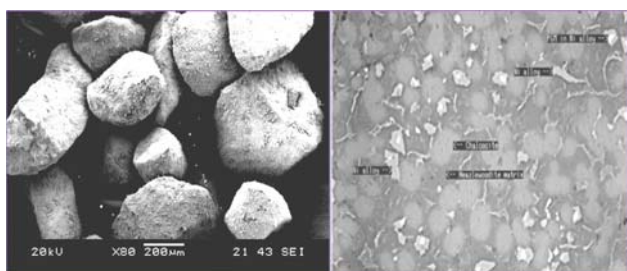


Fig. 2 SEM showing matte particles and major phases present

The as-received matte was wet and dried in an oven. The matte was screened to obtain the desired particle size distribution of $-75\mu\text{m}$. The temperatures investigated were 50°C , 60°C and 70°C .

Element / Chemical	Matte (wt %)
Al_2O_3	0.65
Co	0.29
Cu	23
Ni	37
Pd	0.15
Pt	0.2
S	10
Fe_2O_3	1.1

B. Experimental Procedure and Equipment

The leaching tests were performed in a 3-litre stainless steel vessel provided with baffles, a cover, a thermometer, a pH electrode and fitted with a variable speed overhead stirrer. The stirrer had a blade type impeller and the rate of stirring was set by a tachometer. The set-up was then placed in a water bath with temperature control. Effect of temperature on the leaching of copper matte was investigated. Temperature values ranged between $50\text{--}70^\circ\text{C}$ and the stirring speed was set to 106 rpm, while the particle size fractions was $-75\mu\text{m}$.

The typical experimental procedure was as follows: 3M of ammonia solution was added to the leaching vessel and heated to the desired temperature. Then 66.69g of the matte was

added and the stirrer was set to the required speed. At predetermined time intervals, pH of the reaction mixture was monitored and samples taken using a pipette and immediately filtered. At the end of each experiment, the pulp was filtered.

C. Analysis of Samples

The samples were analysed at the University of Johannesburg: metallurgy and chemistry laboratories. The solution samples were analyzed for Ni and Cu using inductively coupled plasma (ICP) and Atomic absorption spectroscopy (AAS).

IV. RESULTS AND DISCUSSION

The effect of temperature on the leaching behaviour of copper matte was investigated by varying it from 50°C to 70°C while keeping the other variables constant and also to determine what kind of reaction involved.

The results obtained indicated that increasing the temperature from 50°C to 60°C increased both the rate and degree of copper recovery (Fig. 2) but however after 30min copper recovery drops and starts to increase after 45min and decrease again after 95min, this is caused by cementation process as nickel displaces copper. At temperature of 70°C copper recovery decreases and this decrease is caused by the fact that at high temperatures ammonia starts to evaporate into the air. Fig. 4 shows the cumulative recovery of copper at different temperature and that as temperature increases recovery also increases but at temperature of 70°C , the opposite of what is expected from the literature happens.

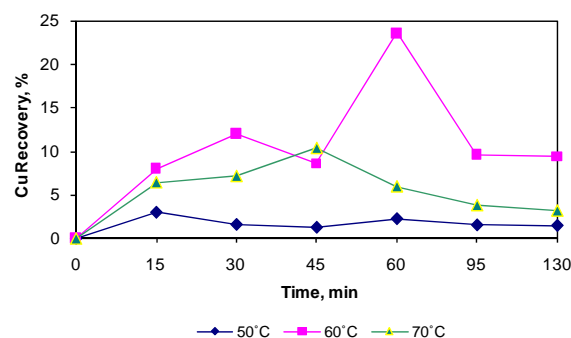


Fig. 3 Copper recoveries as a function of leaching time at different temperatures

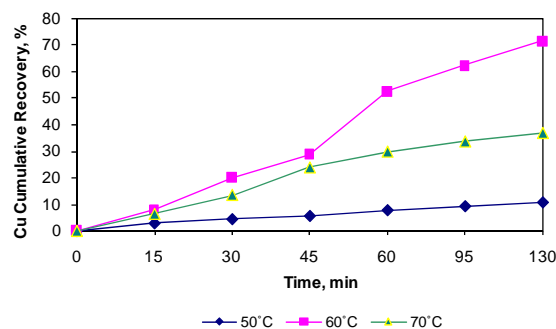


Fig. 4 Copper cumulative recoveries as a function of leaching time at different temperatures

Fig. 5 shows that increasing the temperature from 50°C to 60°C increased both the rate and degree of nickel recovery even though at time interval of 15min the rate of nickel recovered at 50°C was higher than that at 60°C. A temperature range of 60°C to 70°C also showed an increase in the rate of nickel recovery in agreement with literature. The nickel recovery at 70°C started to decrease after 45min compared to that at 60°C that decreased after 60min. This is because ammonia evaporates to the atmosphere at high temperatures. After 60min time interval all the recoveries at all three different temperatures decreased and this is because most of the nickel has been recovered

Fig. 6 indicated the cementation process that took place at optimum temperature of recovery for copper. The recovery of both copper and nickel increased with time up to 30 minutes. After 30min copper recovery started to decrease while nickel recovery continued to increase, that was due to cementation process as nickel displaced copper. Copper recovery started to increase after 45minutes. After 60min both metals recoveries decreased as they have been extracted from the matte.

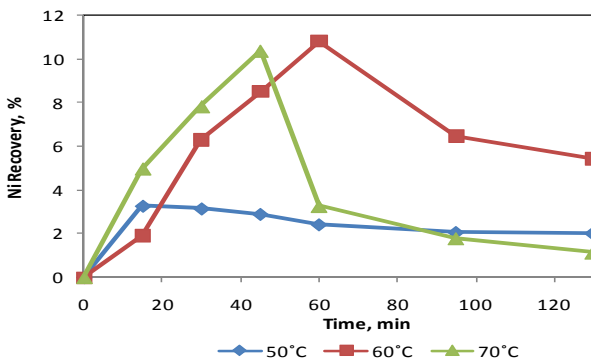


Fig. 5 Nickel recoveries as a function of leaching time at different temperatures

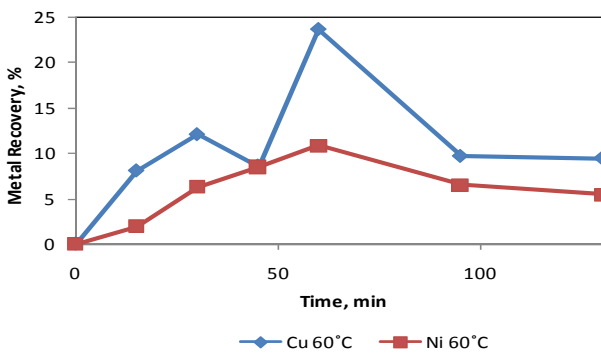


Fig. 6 Comparison of metal recoveries between Copper and Nickel at 60°C

The dissolution kinetics of the metal was characterized with the shrinking core model using copper dissolution kinetics data obtained from the experiments conducted. The equation describing reaction controlled by diffusion $[1-3(1-X)^{2/3}+2(1-X)]$ through surface layer (Fig. 7a) only gave the best fit for 50°C and not at 60°C and 70°C. Equation describing reaction

controlled by a surface chemical reaction $[1-(1-X)^{1/3}]$ (Fig. 7b) only gave the best fit at 50°C and not for 60°C and 70°C. Equation describing reaction controlled by a mixed controlled process $[1-3(1-X)^{2/3}+2(1-X) + a[1-(1-X)^{1/3}]$ (Fig. 7c) only gave the best fit at 50°C and 60°C and not for 70°C.

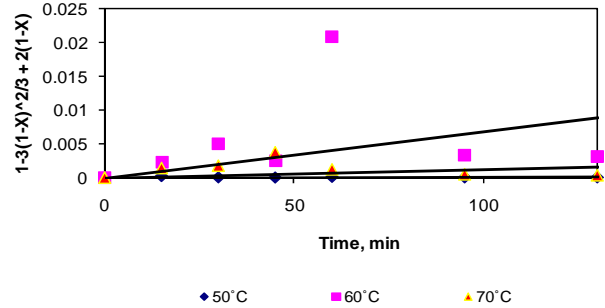


Fig. 7a Plot of $1-3(1-X)^{2/3} + 2(1-X)$ vs time for the leaching of copper at different temperatures for the diffusion controlled reaction

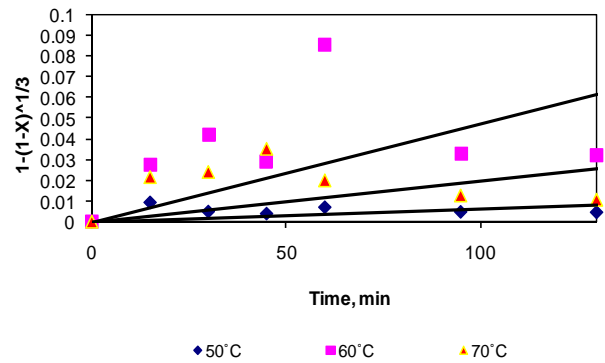


Fig. 7b Plot of $1-(1-X)^{1/3}$ vs time for the leaching of copper at different temperature for the chemically controlled reaction

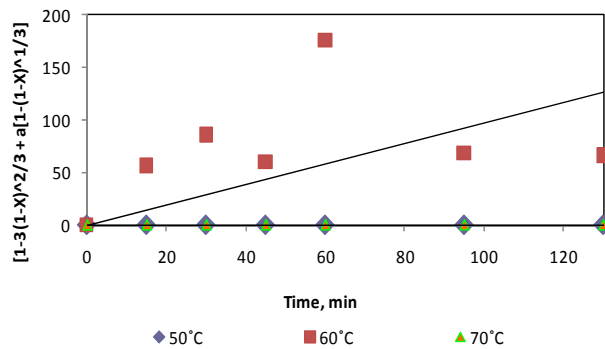


Fig. 7c Plot for $1-3(1-X)^{2/3} + 2(1-X) + a[1-(1-X)^{1/3}]$ vs time for the leaching of copper at different temperature for the mixed controlled reaction

V. CONCLUSION

- The results showed copper recovery increased from the temperature range of 50°C to 60°C, and beyond 60°C recoveries decreased.
- The optimum temperature is 60°C as there was a higher recovery of copper leached and a faster rate of

leaching obtained as compared to the temperatures of 50°C and 70°C.

- None of the three models fits the obtained data at all temperatures.
- The deviation might be caused by the cementation process as the nickel displaces copper.
- The shrinking core model is not a suitable model when using copper dissolution data obtained from the experiment as copper undergoes cementation process.

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