

Technical Report

Systematic Assessment of the Effect of Quantity of Supplied Electricity on the Solution pH during Electro-extraction of Iron from Haematite

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Abstract: Attempt has been made to assess the effect of the quantity of supplied electricity on the solution pH during electro-extraction of metal iron from the ore concentrate. The results of the investigation reveal that the pH of the electrolyte during the electrolytic process increases with increase in the mass of Fe deposited at the cathode as a result of the simultaneous liberation (at the anode) of chlorine gas (acidic) which forms part of the electrolyte. Increase in the quantity of electricity supplied for the electrolytic process increases the pH of the electrolyte since increased supply of electricity for the process translates to increased concentrations of ions migrating to the electrodes. The initial pH of the electrolyte drops at the beginning of the process as a result of the addition of the iron oxide ore. This is attributed to the physiochemical interaction between the ore and electrolyte. At constant process time and voltage, increase in the current supplied increases the mass of Fe deposited on the cathode. [Academia Arena, 2010;2(7):7-10] (ISSN 1553-992X).

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1. Introduction

Electro-winning is the oldest industrial electrolytic process. Sodium metal has been obtained in elemental form for the first time in 1876 by electrolysis of molten sodium hydroxide (Conway and White, 1983).

Several studies on leaching have shown that the solution pH influences the leaching out of metals and other elements from its ore.

Panias et al. (1996) reported that the optimum pH for dissolving iron oxide is pH 2.5 – 3.0. The solution pH governs the distribution of various oxalate ions in the leach system.

Nwoye et al. (2008) derived a model which predicted that the concentration of phosphorus removed is dependent on the final pH of the leaching solution and weight input of the iron oxide ore. The model indicates that the concentration of phosphorus removed is inversely proportional to the product of the weight input of the iron oxide ore and the final pH of the leaching solution.

Nwoye (2008a) predicted that the concentration of haematite dissolved during the leaching process is directly proportional to the final pH of the leaching solution and inversely proportional to

the weight input of the iron oxide ore.

Nwoye (2008b) derived a model for evaluating the final pH of the leaching solution during leaching of iron oxide ore in oxalic acid solution. The model evaluates the pH value as the sum of two parts, involving the % concentrations of Fe and Fe₂O₃ dissolved. It was also found that the model (Nwoye, 2008b) could predict the concentration of Fe or Fe₂O₃ dissolved in the oxalic acid solution at a particular final solution pH by taking Fe or Fe₂O₃ as the subject formula. The prevailing process conditions under which the model works include: leaching time of 30mins., constant leaching temperature of 30°C, average ore grain size; 150µm and 0.1M oxalic acid.

Nwoye (2009) reported that the concentration of phosphorus dissolved in oxalic acid is dependent on the final pH of the leaching solution during leaching of iron oxide ore in oxalic acid solution.

The present work is an attempt to extract iron from its ore using electrolytic method. In this work, the cathode and anode electrodes used are carbon rods (graphite) and the electrolyte, aqua regia which is a combination of hydrochloric and nitric acid.

2. Materials and Methods

86 cm³ of 4M hydrochloric acid (HCl) and 64 cm³ of 4M nitric acid were measured out giving volumes of 344cm³ and 256cm³ respectively. Each of the two solutions was made up to 1000cm³ by addition of distilled water. The two solutions were poured into the electrolytic cell box and the initial pH; 1.75, taken using the pH meter (at the Materials Laboratory of Federal University of Technology, Owerri) before current is supplied to the system. The connecting cables were passed through a rheostat and voltmeter to measure the current flow.

Weighed quantity (30g) of Itakpe iron ore concentrate (as received from National Metallurgical Centre (NMC) Jos) was poured into the aqua raegae electrolyte and thoroughly mixed. A current of 0.042A and 9.5V was allowed to pass through the set-up for 5 minutes after which the cathode electrode was removed and weighed to determine the mass of iron deposited. This was repeated for process duration of 10, 15, 20, 25 and 30 minutes respectively. At these process durations highlighted, the pH of the electrolyte was also taken to know how the current supply affects the solution pH.

3. Results and Discussion

The as-received concentrate used for this work was analyzed chemically to determine the chemical composition of the various elements and compounds present. The result is presented in Table 1.

Table 1: Chemical composition of the iron concentrate used

Element/Compound	%Composition
SiO ₂	17.38
P ₂ O ₅	0.38
Al ₂ O ₃	8.93
CaO	0.36
MgO	0.06
Fe	63.0
Na ₂ O	3.60
K ₂ O	4.20
TiO ₂	0.40

In order to understand the effect of quantity of supplied current on the solution pH, the whole electrolytic system was set-up and run at constant voltage of 9.5V and varied current values of 0.02, 0.04, 0.06, 0.08, and 0.1A for 10minutes process duration respectively. The initial pH of the electrolyte was also maintained at 1.75. Also the pH of the electrolyte was taken for each variation in supplied current.

Following faradays first law of electrolysis (Obi, 1998)

$$Q = It \quad (1)$$

Where

Q = Quantity of electricity (C)

I = Current (A)

t = Time of flow of current (s)

At constant current flow and voltage while process time varies (up to 1800s), the pH of the electrolyte during the electrolytic process increases with increase in the mass of Fe deposited on the cathode as shown in Figure 1.

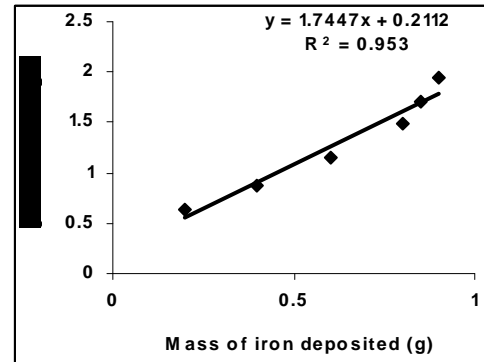


Figure 1: Variation of pH of electrolyte with mass of Fe deposited (at constant current flow and voltage)

It was also observed that increase in the quantity of electricity Q (supplied for the process) increases the pH of the electrolyte. This is shown in Figure 2. This is believed to be correct since increase in the quantity of electricity supplied increases the mass of Fe deposited. This is in agreement with Faradays law (Obi, 1998).

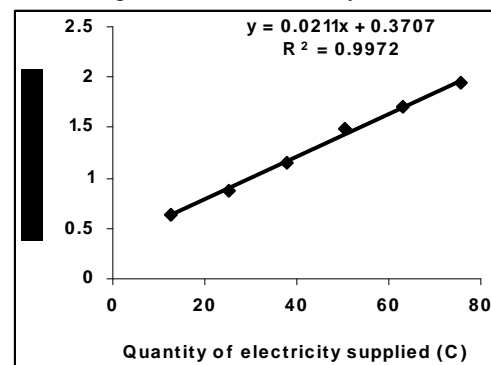


Figure 2: Variation of pH of electrolyte with quantity of electricity supplied (at constant current flow and voltage)

At constant process time and voltage, Figures 3 and 4 shows also that during the electrolytic process, pH of the electrolyte increases with increase in the mass of Fe deposited on the cathode and quantity of electricity supplied respectively. The associated correlation coefficients R are 0.9967 and 0.9989 respectively. Equation (1) shows that quantity of electricity supplied Q is directly proportional and a function of current supplied I. Based on the foregoing, Figures 5 and 6 shows that increase in the supplied current increases the pH of the electrolyte as well as the mass of Fe

deposited. This is because increase in the quantity of electricity Q (supplied for the process) increases the pH of the electrolyte as shown in Figures 2 and 4. The correlation coefficients R associated with Figures 5 and 6 are 0.9934 and 0.9989 respectively. The correlation coefficients of Figures 4 and 6 are the same but the curve gradient of Figure 6 (20.9) is greater than that of Figure 4 (0.0348). Furthermore, the intercept on the Y-axis (0.038) is the same for Figures 4 and 6. This also indicate that both current and quantity of electricity supplied affect the pH of the electrolyte the similarly.

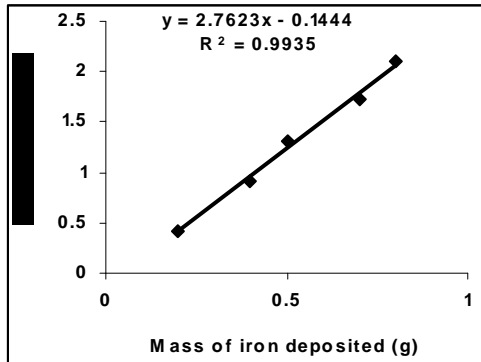


Figure 3: Variation of pH of electrolyte with mass of Fe deposited (at constant process time and voltage)

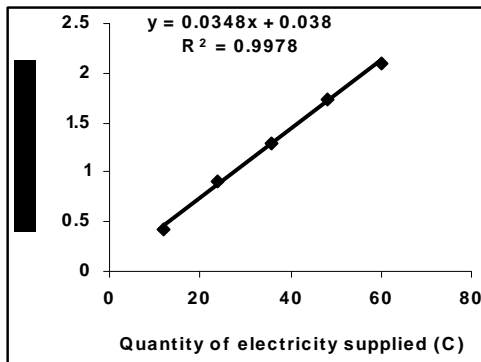


Figure 4: Variation of pH of electrolyte with quantity of electricity supplied (at constant process time and voltage)

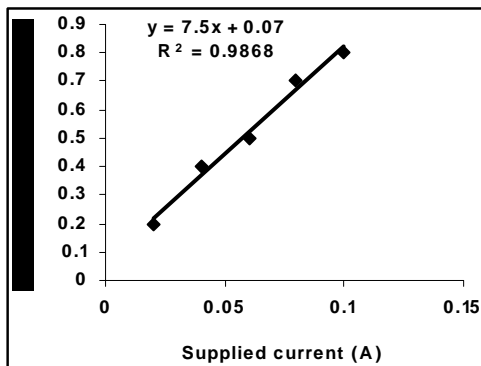


Figure 5: Variation of mass of Fe deposited with supplied current (at constant process time and voltage)

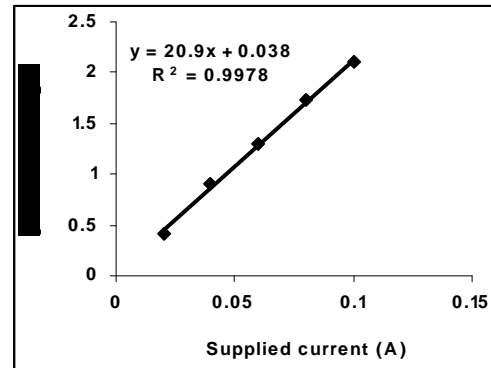
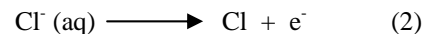


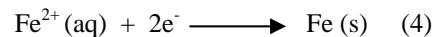
Figure 6: Variation of pH of electrolyte with supplied current (at constant process time and voltage)

Considering that the initial pH of electrolyte before the addition of the ore was 1.75, the pH dropped to lower values at the beginning of the electrolytic process and then increased. The lower pH values obtained at the inception of the process is attributed to the physiochemical interaction between the ore and electrolyte at contact. The increase in the pH of the electrolyte as the mass of Fe deposited increases (Figures 1 and 3) indicate decrease in acidity. This is attributed to the liberation of chlorine gas at the anode, considering the possibility of Cl^- being preferentially discharged even though both Cl^- and NO_3^- migrated to the anode. Based on the foregoing, Cl^- loses an electron at the anode to become electrically neutral Cl atom which pairs up to form chlorine molecules; gas. The anodic reaction gives;



It is believed that since chlorine is part of the electrolyte (HCl) which is acidic, its liberation from the electrolyte decreases the acidity which translates into increases in the pH of the electrolyte.

Similarly Fe is deposited at the cathode as a result of the preferential discharge of Fe^{2+} in place of H^+ at the cathode. Fe^{2+} on being discharged at the cathode gains two electrons and become electrical neutral Fe atom which is then deposited on the cathode. The cathodic reaction gives;



4. Conclusion

Based on the electrolytic extraction of Fe (from its ore) carried out, the following conclusions have been drawn. (1) The pH of the electrolyte during the electrolytic process increases with increase in the mass of Fe deposited at the cathode as a result of the simultaneous

liberation of chlorine gas (acidic) which forms part of the electrolyte.

(2) Increase in the quantity of electricity supplied for the electrolytic process increases the pH of the electrolyte since increased supply of electricity for the process translates to increased concentrations of ions migrating to the electrodes.

(3) The initial pH of the electrolyte drops at the beginning of the process as a result of the addition of the iron oxide ore. This is attributed to the physiochemical interaction between the ore and electrolyte.

(4) At constant process time and voltage increase in the current supplied increases the mass of Fe deposited on the cathode

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