

# Comparative Acid-Leaching Behaviour of a Lithium-Bearing ORE From Kishi, OYO State, Nigeria

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## Research Article

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# Abstract

Lithium is an important strategic element for modern energy-storage technologies, particularly rechargeable lithium-ion batteries. This study investigated the comparative acid-leaching behaviour of a lithium-bearing ore obtained from Kishi, Oyo State, Nigeria. Preliminary laboratory characterization reported 1.36%  $\text{Li}_2\text{O}$  and 1.76%  $\text{H}_2\text{O}$ . Equal portions of 1.00 g of pulverized ore were separately contacted with 20 mL of 0.5 M HCl, 20 mL of 0.5 M  $\text{H}_2\text{SO}_4$  and 20 mL of distilled water as a control. Experiments were conducted at room temperature under continuous stirring for 20 minutes. After filtration and drying, residual masses were determined.  $\text{H}_2\text{SO}_4$  produced the lowest residual mass (0.40 g), corresponding to 60% apparent mass reduction; HCl produced 0.50 g residue and 50% apparent mass reduction; while the water control produced 0.60 g residue and 40% apparent mass reduction. The observed trend was  $\text{H}_2\text{SO}_4 > \text{HCl} > \text{H}_2\text{O}$ . The result suggests that sulfuric acid promoted greater apparent dissolution under the investigated conditions. Because lithium concentration in the leachates was not quantitatively determined, the results represent apparent ore dissolution rather than lithium recovery.

## 1. Introduction

Lithium is increasingly important in materials chemistry and energy technology because of its use in rechargeable batteries and energy-storage systems. Chemical extraction from mineral resources is consequently receiving growing attention. Hydrometallurgy transfers valuable elements from solid materials into aqueous solution through controlled chemical reactions, followed by separation and recovery. Acid leaching is an established hydrometallurgical approach, with sulfuric and hydrochloric acids among the commonly investigated lixiviants. Hard-rock lithium resources may contain lithium in aluminosilicate and related mineral structures. The effectiveness of acid leaching depends on mineralogy, acid concentration, solid-to-liquid ratio, temperature, contact time, particle size and mineral liberation. Conventional sulfuric-acid processing of spodumene normally involves thermal transformation before acid digestion; therefore, the present room-temperature experiment is a preliminary leachability comparison rather than an industrial process simulation. The ore investigated was obtained from Kishi, Oyo State, Nigeria. CCBC Testing Laboratory Nigeria reported 1.36%  $\text{Li}_2\text{O}$  and 1.76%  $\text{H}_2\text{O}$  for the sample. The present study focuses on the chemistry of its interaction with dilute HCl and  $\text{H}_2\text{SO}_4$  under identical laboratory conditions.

### 1.1 Aim

To investigate the comparative acid-leaching behaviour of a lithium-bearing ore from Kishi, Oyo State, using hydrochloric acid and sulfuric acid under controlled laboratory conditions.

### 1.2 Objectives

To investigate apparent dissolution in 0.5 M HCl; investigate apparent dissolution in 0.5 M  $\text{H}_2\text{SO}_4$ ; compare acid-assisted dissolution with distilled water; determine residual mass; compare the two acids

under identical conditions; and provide preliminary chemical information for subsequent lithium-recovery investigations.

## 2. Materials and Methods

### 2.1 Sample Collection and Characterization

The lithium-bearing ore was obtained from Kishi, Oyo State, Nigeria, and pulverized before leaching. An independent CCBC Testing Laboratory Nigeria report identified the sample as lithium ore and reported  $\text{Li}_2\text{O} = 1.36\%$  and  $\text{H}_2\text{O} = 1.76\%$ . The report was issued on 10 August 2026 and identified the sample/test report as 202607-5497.

### 2.2 Reagents

0.5 M hydrochloric acid (HCl), 0.5 M sulfuric acid ( $\text{H}_2\text{SO}_4$ ), and distilled water.

### 2.3 Experimental Conditions

For each treatment, 1.00 g of ore was contacted with 20 mL solution. HCl and  $\text{H}_2\text{SO}_4$  were each 0.5 M; the control was distilled water. All experiments were conducted at room temperature with continuous stirring for 20 minutes. The solid-to-liquid ratio was 1:20 g/mL.

### 2.4 Leaching Procedure

Approximately 1.00 g of pulverized ore was placed in each reaction vessel. Twenty millilitres of 0.5 M HCl was added to the first portion, 20 mL of 0.5 M  $\text{H}_2\text{SO}_4$  to the second, and 20 mL distilled water to the third. Each mixture was continuously stirred at room temperature for 20 minutes. The mixtures were filtered, and the recovered residues were dried and weighed.

### 2.5 Calculation

Apparent mass reduction (%) =  $[(M_1 - M_2) / M_1] \times 100$ , where  $M_1$  is the initial ore mass and  $M_2$  is the dried residual mass. Lithium recovery was not calculated because lithium concentration in the leachates was not measured.

## 3. Results

Table 1. Comparative apparent dissolution of Kishi lithium-bearing ore

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Comparative apparent dissolution of Kishi lithium-bearing ore

| Treatment                      | Initial (g) | Residue (g) | Reduction (g) | Reduction (%) |
|--------------------------------|-------------|-------------|---------------|---------------|
| HCl                            | 1.00        | 0.50        | 0.50          | 50            |
| H <sub>2</sub> SO <sub>4</sub> | 1.00        | 0.40        | 0.60          | 60            |
| Water control                  | 1.00        | 0.60        | 0.40          | 40            |

Treatment Initial (g) Residue (g) Reduction (g) Reduction (%) HCl 1.00 0.50 0.50 50 H<sub>2</sub>SO<sub>4</sub> 1.00 0.40 0.60 60 Water control 1.00 0.60 0.40 40 The apparent dissolution trend was H<sub>2</sub>SO<sub>4</sub> > HCl > H<sub>2</sub>O.

**Figure 1. Comparative apparent mass reduction following leaching.**

## 4. Discussion

The H<sub>2</sub>SO<sub>4</sub> treatment produced the highest apparent mass reduction (60%), compared with 50% for HCl and 40% for the water control. Because ore mass, solution volume, acid molarity, temperature, stirring and contact time were held constant, the higher reduction obtained with H<sub>2</sub>SO<sub>4</sub> indicates greater apparent dissolution under the conditions tested. Acid leaching involves proton attack on susceptible mineral structures and transfer of released species into the aqueous phase. The exact pathway depends on the mineral phases present. The simplified reaction  $\text{Li}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{Li}_2\text{SO}_4 + \text{H}_2\text{O}$  illustrates possible conversion of an oxide component to a soluble sulfate, but does not imply that free Li<sub>2</sub>O is the mineral phase in the ore. In lithium aluminosilicates, lithium is structurally incorporated into the mineral lattice and dissolution is more complex. The HCl result also indicates substantial dissolution. Hydrochloric acid supplies H<sub>2</sub> for acid attack and chloride ions that participate in aqueous metal chemistry. Its lower apparent dissolution than H<sub>2</sub>SO<sub>4</sub> in this experiment suggests lower bulk dissolution under the specific conditions used; this should not be generalized to all lithium ores.

### 4.1 Importance of the Water Control

The 40% apparent mass reduction in the water control is important because it shows that not all measured mass loss can be attributed to acid attack. Possible contributors include dissolution of water-soluble constituents, disaggregation of the powdered sample, fine-particle loss during filtration, transfer losses and incomplete residue recovery. Relative to water, HCl gave an additional 10 percentage points and H<sub>2</sub>SO<sub>4</sub> an additional 20 percentage points of apparent mass reduction.

### 4.2 Apparent Dissolution Versus Lithium Recovery

The measured residue mass cannot be used directly to calculate lithium recovery. The material removed during leaching may contain lithium-bearing phases together with other soluble or partially soluble mineral constituents. Quantitative lithium analysis of the leachates is required before lithium extraction efficiency can be reported.

## 4.3 Theoretical Lithium Content

At 1.36%  $\text{Li}_2\text{O}$ , 1.00 g of the original ore theoretically contains 13.6 mg  $\text{Li}_2\text{O}$ , corresponding to approximately 6.32 mg elemental Li. This is a theoretical starting content, not the amount recovered.

## 5. Significance of the Study

The study provides preliminary chemical-processing information on a locally sourced lithium-bearing material. It demonstrates measurable  $\text{Li}_2\text{O}$  in the sample, enhanced apparent dissolution under acidic conditions relative to water, and greater apparent dissolution with sulfuric acid than hydrochloric acid under the selected conditions. The work therefore provides a starting point for further hydrometallurgical investigation of Kishi lithium-bearing material and contributes to research on energy-related materials and local mineral-resource utilization.

## 6. Limitations

The experiment used a single set of measurements rather than replicates; lithium concentration in the leachates was not quantitatively determined; the mineralogical identity of the lithium-bearing phase was not established; the large water-control mass reduction introduces uncertainty from dissolution and/or physical losses; only 20 minutes and one acid concentration were studied; and the experiment was conducted at room temperature without thermal pretreatment.

## 7. Conclusion

At 0.5 M acid concentration, 20 mL solution volume, room temperature, continuous stirring and 20 minutes leaching time,  $\text{H}_2\text{SO}_4$  produced the highest apparent mass reduction (60%), followed by HCl (50%), while water produced 40%. The trend was  $\text{H}_2\text{SO}_4 > \text{HCl} > \text{H}_2\text{O}$ . Sulfuric acid was therefore more effective than hydrochloric acid in promoting apparent dissolution under the investigated conditions. The result should not be described as 60% lithium recovery because lithium in the leachate was not measured. The findings provide a useful preliminary foundation for further chemical investigation of lithium-bearing materials from Kishi.

## 8. Recommendations

Future work should include triplicate experiments; optimization of  $\text{H}_2\text{SO}_4$  concentration, leaching time, temperature, particle size and solid-to-liquid ratio; quantitative lithium determination by AAS, ICP-OES, ICP-MS or another validated technique; XRD/XRF characterization; analysis of co-leached elements; investigation of downstream lithium recovery; and evaluation of reagent consumption and environmental implications.

## Declarations

## **Data Availability**

Salaudeen Hafisu: Conceptualization, methodology, investigation, data collection, analysis, and manuscript preparation. Adeagbo Comfort Tolu: review and editing. Both authors read and approved the final manuscript.

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

## **Author Contributions**

The authors declare that they have no competing interests.

## **Competing Interests**

Ethics, Consent to Participate, and Consent to Publish declarations: not applicable.

## **Ethics, Consent to Participate, and Consent to Publish declarations**

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## Figures

Image not available with this version

**Figure 1**

**Comparative apparent mass reduction following leaching.**