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MAXIMIZING THE EXTRACTION OF ALUMINUM AND ITS COMPOUNDS FROM ALUMINOSILICATES: LABORATORY AND INDUSTRIAL STUDIES

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ABSTRACT: *The sustainable development of inorganic chemical technology is closely associated with the efficient use of natural resources and the adoption of resource-saving processing methods for local mineral raw materials. This study focuses on the comprehensive processing of Uzbekistan's aluminosilicate rocks—such as kaolin, bauxite, and zeolite—for aluminum extraction. The chloride decomposition method was investigated as an alternative to conventional acid and alkaline processes. Laboratory experiments were conducted to evaluate the effects of temperature, chloride concentration, and processing duration on aluminum extraction efficiency. The results demonstrate that chloride decomposition provides higher aluminum yields (up to 94%) with reduced energy consumption and environmental impact compared to sulfuric acid leaching. The findings are relevant for establishing low-waste, locally sourced production technologies, contributing to Uzbekistan's industrial independence and environmental sustainability.*

KEYWORDS: *Aluminosilicates; Chloride decomposition; Aluminum extraction; Uzbekistan clays; Alumina production; Industrial sustainability*

1. INTRODUCTION

Modern advancements in inorganic chemical technology emphasize the rational utilization of natural mineral resources and the adoption of resource-efficient processing methods. In Uzbekistan, aluminosilicate deposits—comprising kaolins, bauxites, and zeolites—present a significant potential for aluminum oxide and coagulant production. However, conventional processing technologies are energy-intensive and environmentally burdensome.

One promising approach is chloride decomposition, which allows conversion of aluminosilicates into soluble chlorides of aluminum and other metals under moderate conditions. This method, characterized by reduced waste generation and reagent recyclability, supports the production of high-purity

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aluminum compounds and coagulants for water treatment.

The main objective of this study is to optimize chloride decomposition conditions for Uzbekistan's local aluminosilicate materials to maximize aluminum extraction efficiency while minimizing silicon and iron losses.

2. MATERIALS AND METHODS

2.1. Raw Materials

Kaolin and bentonite-like clays from the Angren, Kuvasay, and Varzik deposits were selected. The samples were dried, crushed (<150 µm), and homogenized to ensure experimental reproducibility.

2.2. Analytical Methods

X-ray diffraction (XRD) and fluorescence (XRF) analyses were used to determine the mineral composition and chemical elements, while petrochemical and microscopic analyses were applied to study morphology and impurities.

2.3. Experimental Procedures

Two main processing methods were evaluated:

- **Chloride decomposition:** calcination (550–650 °C, 1–2 h), treatment with HCl (20–30%, 100–120 °C, 4–6 h), followed by filtration and precipitation of aluminum hydroxide.
- **Sulfuric acid leaching:** calcination (700–800 °C), leaching with H_2SO_4 (2–6 M, 85–125 °C, 1–5 h), and hydrolysis to obtain aluminum hydroxide.

2.4. Efficiency Calculations

Extraction efficiency was determined as:

$$\eta_{al} = (m_{al}\_solution / m_{al}\_raw) \times 100\%$$

3. Results and Discussion

3.1. Composition of Raw Materials

The Angren clay contained 33–35% Al_2O_3 and low Fe_2O_3 (2–3%), while Kuvasay and Varzik samples had higher silica and iron impurities. These characteristics influenced decomposition efficiency and product purity.

3.2. Chloride Decomposition Performance

Under optimal conditions (110–120 °C, 25% HCl, 5 h), aluminum extraction reached:

- 92–94% for Angren,
- 85–88% for Kuvasay,
- 80–83% for Varzik.

Chloride decomposition provided higher selectivity and lower Fe/Al ratios, yielding alumina with 97–98% purity.

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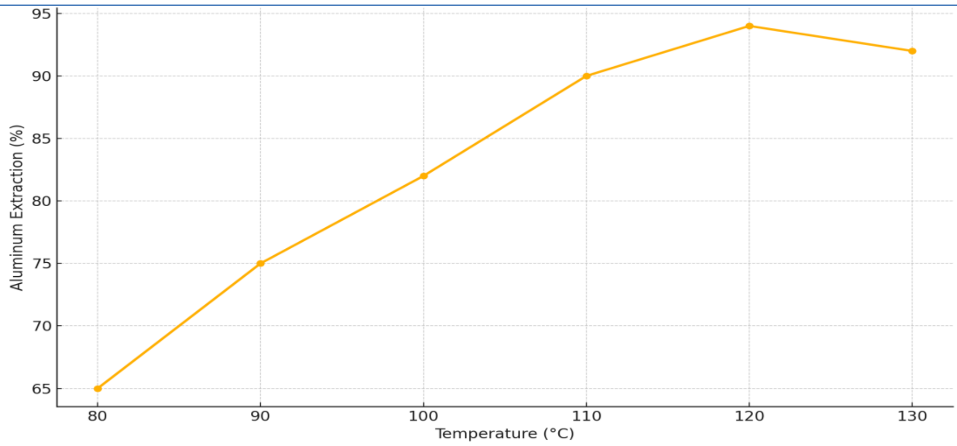

Figure 1. Aluminum extraction versus temperature (°C).

3.3. Sulfuric Acid Leaching

Sulfuric acid leaching achieved up to 88–90% extraction at 4–5 M H_2SO_4 and 110–115 °C but generated more waste and iron sulfate residues.

3.4. Influence of Technological Parameters

Increasing temperature up to 120 °C enhanced aluminum recovery by 5–7%, while higher acid concentration (>25% HCl) slightly improved yield but increased reagent consumption. Reaction time beyond 5 hours had negligible effect, allowing energy savings.

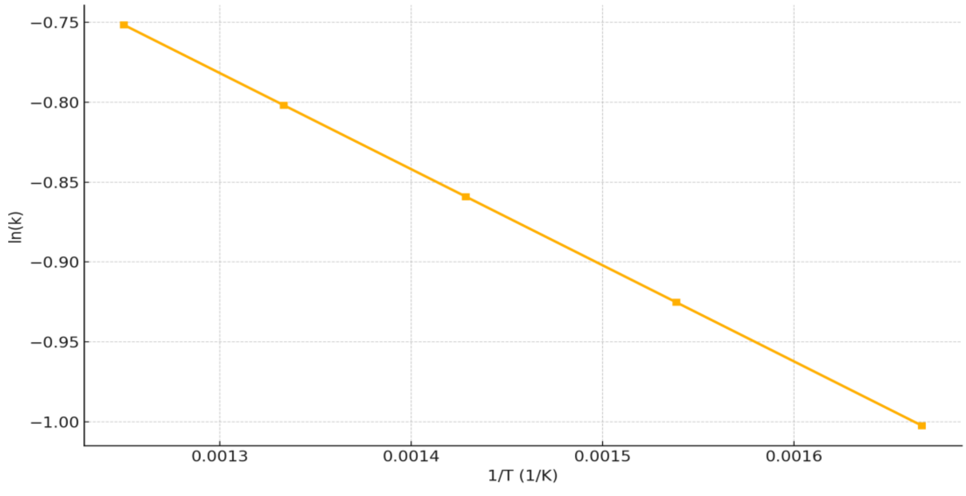

Figure 2. Arrhenius plot (ln k vs 1/T) for aluminum extraction kinetics.

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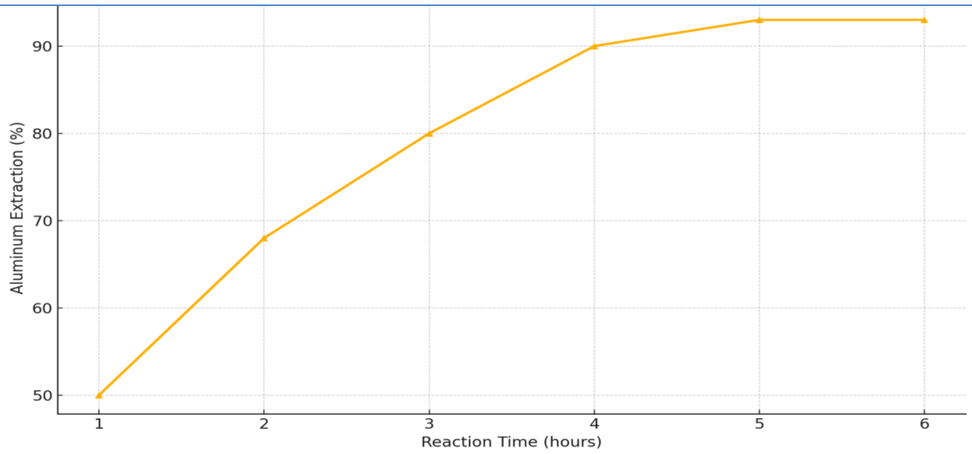

Figure 3. Aluminum extraction as a function of reaction time at various temperatures.

3.5. Comparative Evaluation

Chloride decomposition demonstrated superior efficiency and selectivity compared to sulfuric acid leaching. The solid residues containing SiO_2 can be reused in construction materials, contributing to a zero-waste cycle.

4. CONCLUSION

This research confirms the feasibility of processing Uzbekistan's aluminosilicate clays into high-purity alumina using chloride decomposition. Aluminum extraction efficiency reached 94% with minimal impurities. Angren clays showed the best industrial potential. Sulfuric acid leaching, while effective, produced more waste. The proposed technology supports sustainable, low-cost, and environmentally friendly aluminum compound production based on domestic raw materials.

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