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Investigating Precipitation Behavior of Leached Allanite Rare Earth Ore in Sulfate Solution System

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Introduction

- Rare earth elements (REEs) (i.e., scandium, yttrium, lanthanoids) have significant value for energy infrastructure, decarbonization, and defense technologies.
- Recent studies on allanite REE ore:
 - Identified and characterized mineralogy and liberation potential.
 - Assessed comminution and beneficiation potential.
 - Compared REE recovery of direct sulfuric acid leaching to sulfuric acid baking.
- Purification of the leachate typically follows leaching in most hydrometallurgical process flowsheets.
- Precipitation is the selective removal of one or more major impurities (i.e., undesirable metal ions) via precipitation [1].
- Before the final step in the hydrometallurgical process (i.e., metal recovery), targeted removal of unwanted species without significant loss of valuable metals must occur.
- The goal of this research is promoting a deeper understanding of the precipitation behavior of allanite systems in sulfate solutions.

Research Questions

- How does material type affect precipitation behavior?
- How does particle size affect precipitation behavior?
- How does pre-leach treatment affect precipitation behavior?
 - Acid baking
 - Concentration

Methods

- Primary feedstocks were filtered leachates generated from acid baking and direct leaching representative subsurface (core) and near-surface (surface) allanite-based ores from Halleck Creek, Wyoming.
- After 60 to 180 min of leaching at 75 °C, solids were removed from leachates via vacuum filtration.
- The 170 ± 5 mL leachate was transferred into a 250 mL beaker (Pyrex) equipped with stir bar set to 450 rpm.
- Sodium hydroxide (2 to 12 M) was used to increase pH to 6.0 in 0.5 increments without exceeding > 3 °C above starting temperature.
- Liquid samples removed at each 0.5 pH intervals for elemental analysis via ICP-OES.
- Upon completion of test, precipitates were filtered via vacuum filtration, dried, pulverized, and digestion for elemental and mineralogical analysis via ICP-OES and XRD, respectively.

Results

Material Type

- Core (Figure 1) and surface (Figure 2) material demonstrate different iron precipitation behavior.
 - Fe behavior in core tests indicates 40-50% ferric form.
 - Fe behavior in surface tests indicates 80-90% ferrous form.

Particle Size

- Core (Figure 1) and surface (Figure 2) material demonstrate similar behavior across all particle sizes.
 - Si may be an exception, awaiting ICP-MS validation.

Pre-Leach Treatment

- Concentrated 150 µm core leachate has different iron precipitation behavior when acid baked at 200 °C (Figure 3) than observed in direct leaching (Figure 4).
 - Acid baking may reduce ferric iron to ferrous during process.
 - Improved separation efficiency suggests technoeconomic analysis is needed to see if the added value in purification steps outweighs increased capital and operating costs associated with acid baking.

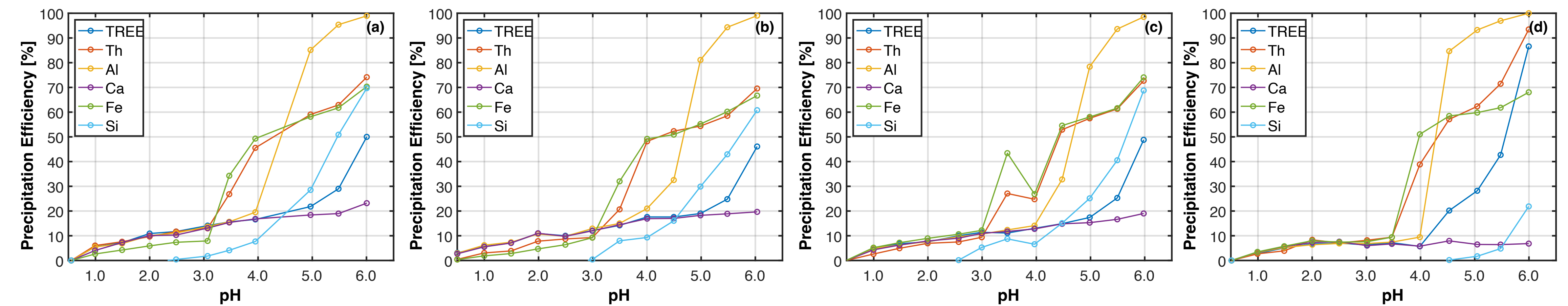


Figure 1. Precipitation efficiency versus pH for (a) pulverized, (b) 150 µm, (c) 500 µm, and (d) crushed (6.5 mm) core material after 180 min direct leach with 1:1 solid to sulfuric acid at 75 °C.

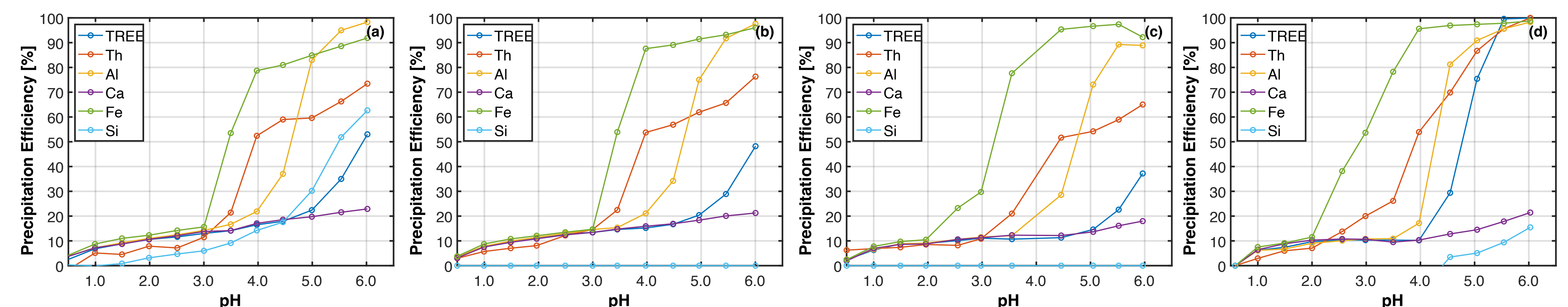


Figure 2. Precipitation efficiency versus pH for (a) pulverized, (b) 150 µm, (c) 500 µm, and (d) crushed (4.1 mm) surface material after 180 min direct leach with 1:1 solid to sulfuric acid at 75 °C.

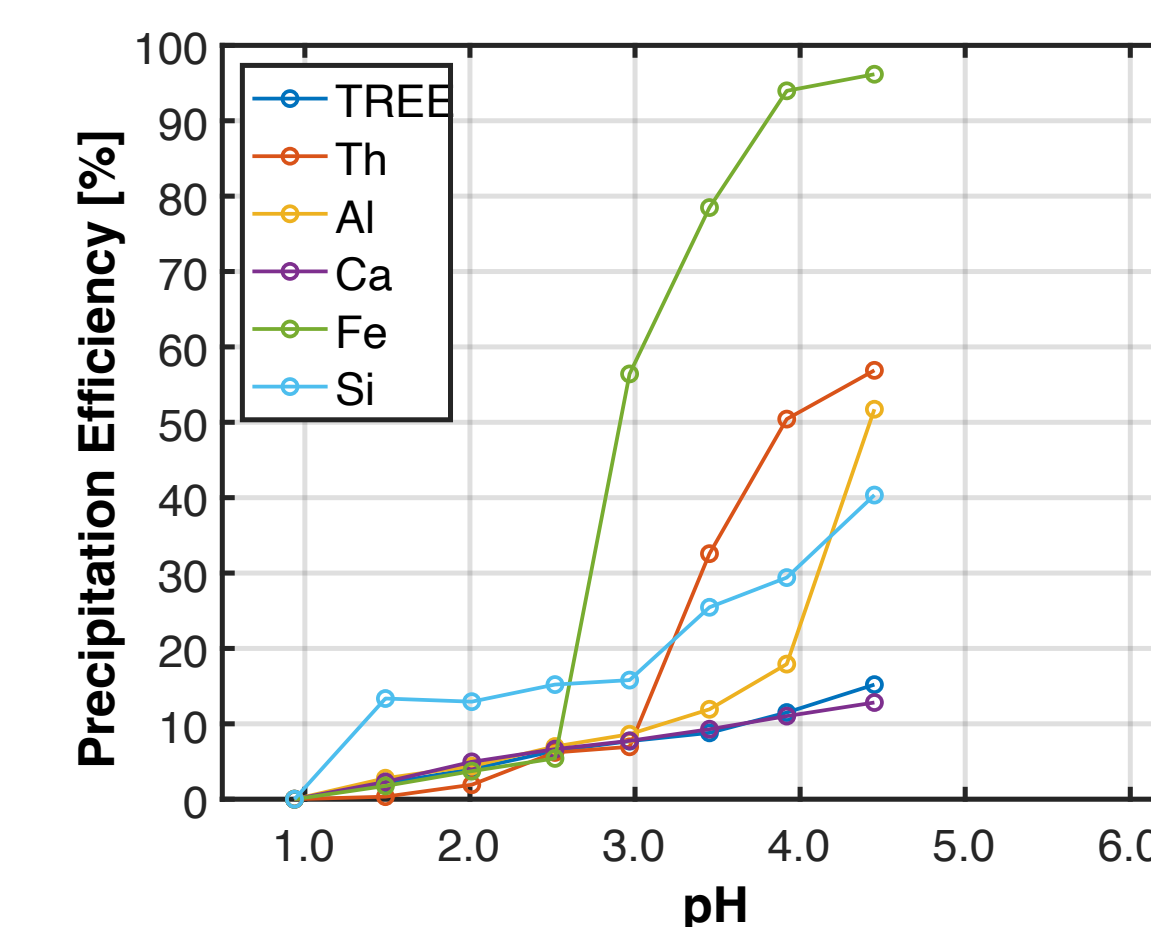


Figure 3. Precipitation efficiency versus pH for 150 µm concentrated core material acid baked at 200 °C with 1:1 solid to sulfuric acid at 75 °C.

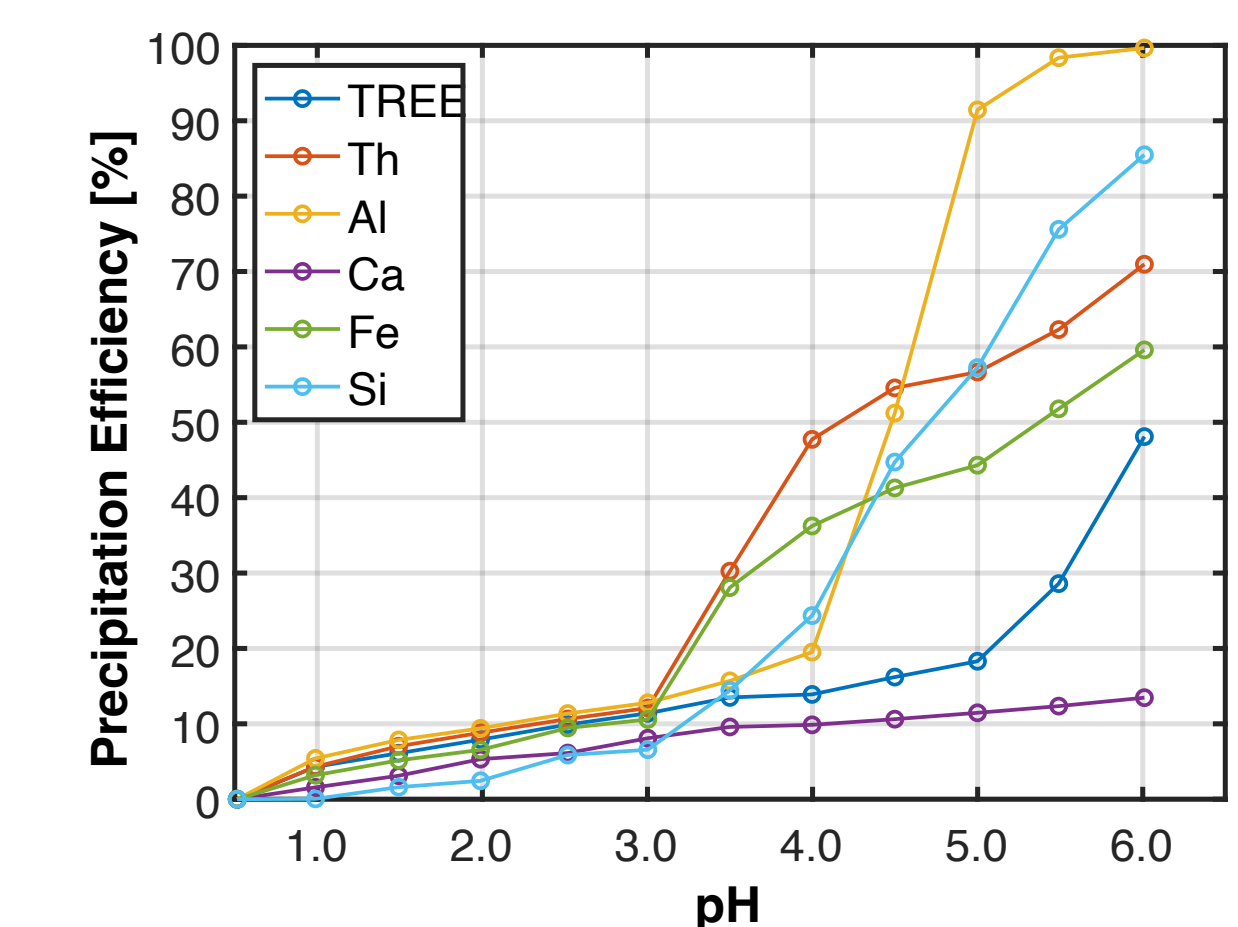


Figure 4. Precipitation efficiency versus pH for 150 µm concentrated core material after 180 min direct leach with 1:1 solid to sulfuric acid at 75 °C.

Conclusions

- The mineralogy present in different allanite bearing ores may impact precipitation behavior.
 - Core material appears to have half ferric iron.
 - Surface material appears to have predominantly ferrous iron.
- Particle size does not appear to have an impact on precipitation behavior.
 - Thus, particle size should be selected to maximize upstream performance.
- Single stage precipitation of direct leached 500 µm core concentrate at pH 5 could further support large scale, low-cost process [2].
- Further research questions need to be addressed include:
 - Can peroxide reduction improve TREE and Fe separation?
 - How do carbonate precipitants affect precipitation behavior?

References

- [1] W. Zhang, R. Honaker, *Minerals Engineering* **2020**, 153, 106382.
- [2] American Rare Earths. (2023, February 24). *Further Upgrade to Halleck Creek Rare Earths Project*. Retrieved from <https://tinyurl.com/2ju3vctk>.

Acknowledgments

This work is supported by SynBREE (HR001121S0035-EMBER-PA-013).

