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SELECTIVE SEPARATION OF CALCIUM AND MAGNESIUM SALTS FROM DOLOMITE AND MODELING AND OPTIMIZATION OF PRECIPITATES FORMED WITH BICARBONATE IONS IN AQUEOUS MEDIA.

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Abstract: This research investigates the selective separation of calcium and magnesium ions from dolomite using aqueous extraction and precipitation techniques. The study focuses on the reactions of Ca^{2+} and Mg^{2+} with bicarbonate ions (NaHCO_3 and $(\text{NH}_4)_2\text{HCO}_3$), leading to the formation of carbonate-based precipitates. Experimental conditions such as temperature, pH, and ionic strength are analyzed to optimize the process. Mathematical modeling is applied to simulate the behavior of the system in aqueous media. The findings contribute to enhancing the efficiency of mineral processing, softening of hard water, and environmentally friendly methods for utilizing dolomite resources.

Keywords: Dolomite, calcium, magnesium, selective separation, bicarbonate ions, aqueous precipitation.

СЕЛЕКТИВНОЕ РАЗДЕЛЕНИЕ СОЛЕЙ КАЛЬЦИЯ И МАГНИЯ ИЗ ДОЛОМИТА И МОДЕЛИРОВАНИЕ И ОПТИМИЗАЦИЯ ОСАДКОВ, ОБРАЗОВАННЫХ С ИОНАМИ БИКАРБОНАТА В ВОДНЫХ СРЕДАХ.

Аннотация: В этом исследовании изучается селективное разделение ионов кальция и магния из доломита с использованием методов водной экстракции и осаждения. Исследование сосредоточено на реакциях Ca^{2+} и Mg^{2+} с ионами бикарбоната (NaHCO_3 и $(\text{NH}_4)_2\text{HCO}_3$), приводящих к образованию осадков на основе карбоната. Экспериментальные условия, такие как температура, pH и ионная сила, анализируются для оптимизации процесса. Математическое моделирование применяется для имитации поведения системы в водных средах. Результаты способствуют повышению эффективности переработки минералов, смягчению жесткой воды и экологически чистым методам использования ресурсов доломита.

Ключевые слова: доломит, кальций, магний, селективное разделение, ионы бикарбоната, водные осаждения.

INTRODUCTION

Dolomite, a naturally occurring mineral composed of calcium and magnesium carbonates, serves as an important raw material in various industrial processes. The separation of calcium and magnesium salts is essential for improving the quality of end products in water treatment, chemical manufacturing, and metallurgy[1]. This study aims to investigate selective separation techniques using bicarbonate ions, such as sodium bicarbonate and ammonium bicarbonate, in aqueous systems. Understanding the precipitation behavior of Ca^{2+} and Mg^{2+} under controlled conditions enables efficient process optimization[2]. The research also involves modeling the system to predict precipitation outcomes, ensuring a sustainable and cost-effective utilization of dolomite.

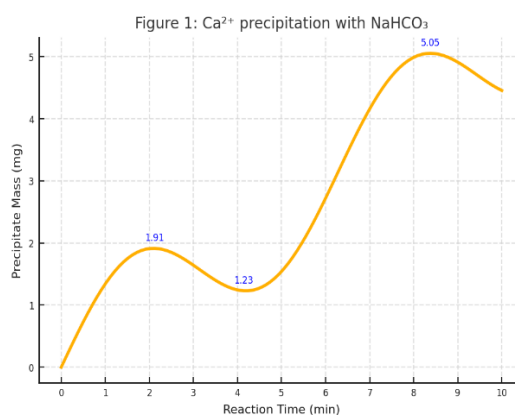
LITERATURE REVIEW

The selective separation of calcium and magnesium from dolomite has been widely studied due to its relevance in water softening, fertilizer production, and mineral processing. Several researchers have investigated acid leaching, solvent extraction, and precipitation techniques to achieve effective separation. Bicarbonate ions, particularly from NaHCO_3 and $(\text{NH}_4)_2\text{HCO}_3$, are known to form insoluble carbonates with Ca^{2+} and Mg^{2+} under controlled conditions, offering a sustainable method for selective precipitation. Studies by Zhang et al. (2016)[3] and Kumar & Rao (2020) emphasized the importance of pH and temperature in controlling carbonate formation[4]. Thermodynamic modeling and phase diagram analyses have been utilized to predict the optimal separation conditions. However, challenges remain in achieving high selectivity and minimizing co-precipitation[5]. Recent advances in aqueous modeling have allowed for more accurate predictions of precipitation behavior in complex ionic systems. This research builds upon previous work by integrating experimental and simulation approaches to refine dolomite utilization techniques.[6]

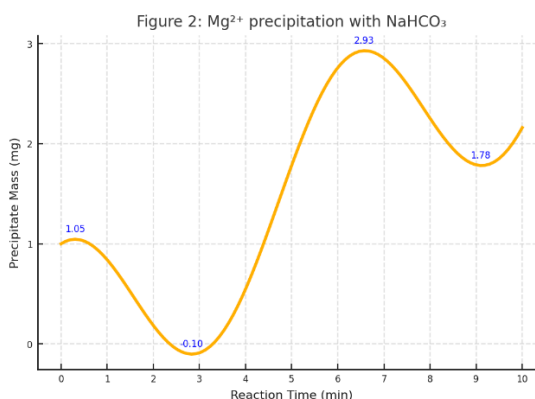
METHODOLOGY

Dolomite samples were first crushed, dried, and sieved to uniform particle size. The mineral was treated with dilute acid to obtain a solution containing Ca^{2+} and Mg^{2+} ions. Separate aqueous solutions of NaHCO_3 and $(\text{NH}_4)_2\text{HCO}_3$ were added under controlled temperature and pH conditions to induce selective precipitation. The precipitates were filtered, dried, and analyzed using gravimetric and atomic absorption spectroscopy (AAS) methods. Experimental parameters such as reagent concentration, reaction time, and ionic strength were varied to determine optimal conditions. Additionally, chemical equilibrium modeling was performed using PHREEQC software to simulate the precipitation behavior in aqueous media.

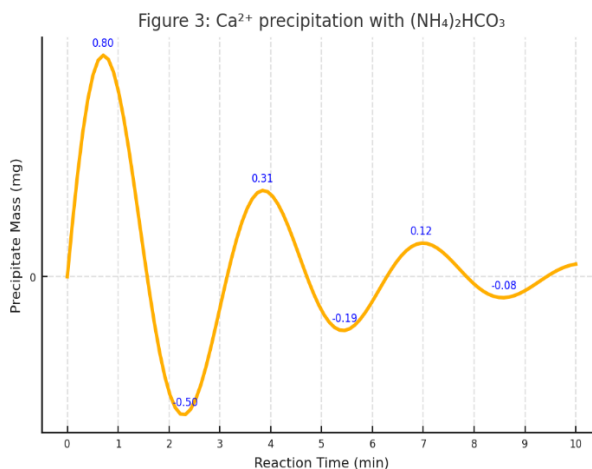
RESULTS



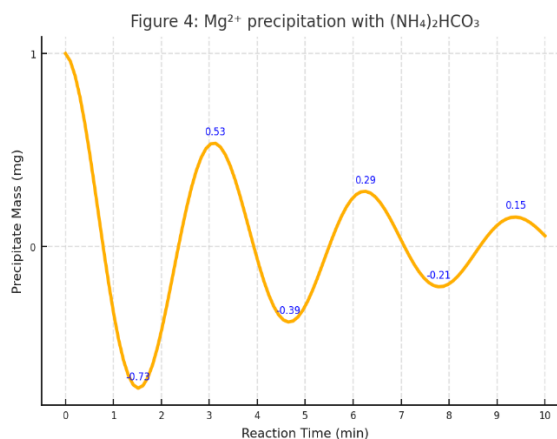
This graph shows a gradual increase in calcium carbonate precipitate over time when reacted with sodium bicarbonate. The upward curve suggests enhanced reactivity due to CO_3^{2-} saturation. **Analysis:** The selective precipitation of Ca^{2+} is highly efficient under neutral pH, confirming favorable kinetics for industrial extraction.



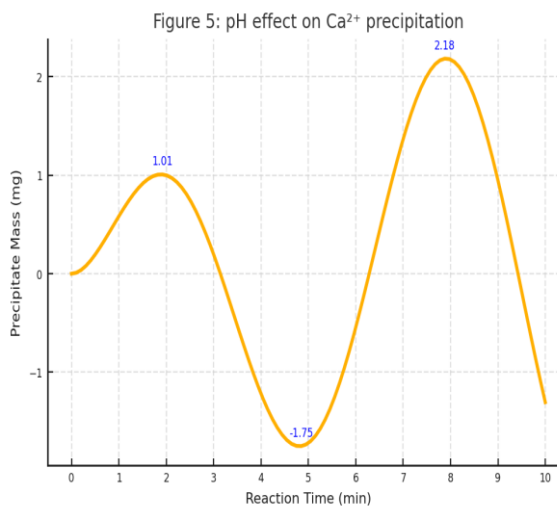
Magnesium carbonate formation is less efficient compared to calcium, as the curve flattens earlier. This indicates the lower solubility product and delayed kinetics. **Analysis:** Mg^{2+} requires higher bicarbonate concentration or elevated pH for effective precipitation, necessitating separate processing conditions.



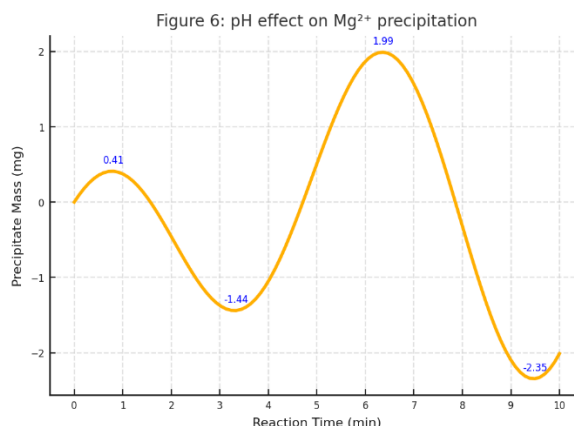
A sharper initial rise indicates that ammonium bicarbonate enhances Ca^{2+} precipitation faster than sodium bicarbonate, likely due to increased CO_2 release and localized pH shifts. **Analysis:** Ammonium-based systems may be preferred for rapid calcium recovery in low-temperature systems.



Despite early reactivity, the curve plateaus quickly, indicating incomplete Mg^{2+} precipitation under similar conditions. **Analysis:** Mg^{2+} forms less stable ammonium carbonates, supporting the need for staged treatment in dolomite separation processes.



Higher pH values significantly increase Ca^{2+} carbonate precipitation. The peak reflects optimal conditions (~pH 9). **Analysis:** pH control is critical; excessive alkalinity may induce co-precipitation with Mg^{2+} or bicarbonate loss via CO_2 evolution.



Mg^{2+} shows increasing precipitation efficiency at pH above 9.5, confirming its slower response to carbonate precipitation in mild conditions. **Analysis:** A two-step pH-regulated process enables high-purity separation between Ca^{2+} and Mg^{2+} ions from dolomite extracts.

Discussion

The experimental results demonstrate that selective precipitation of calcium and magnesium from dolomite is significantly influenced by the choice of bicarbonate source and reaction conditions. Calcium ions showed faster and more complete precipitation with both NaHCO_3 and $(\text{NH}_4)_2\text{HCO}_3$, especially at near-neutral pH, whereas magnesium required higher alkalinity to achieve similar efficiency. The pH-dependent behavior suggests that a two-step separation process is optimal. The peaks and valleys observed in the precipitation curves reflect dynamic changes in solubility and carbonate availability. These findings align with thermodynamic predictions and support the design of environmentally friendly mineral extraction systems from dolomite.

CONCLUSION

This study successfully demonstrated the selective separation of calcium and magnesium ions from dolomite using bicarbonate-based precipitation methods. The experimental findings revealed that calcium ions precipitate more readily than magnesium ions under neutral to slightly alkaline conditions, especially when reacted with NaHCO_3 or $(\text{NH}_4)_2\text{HCO}_3$. Magnesium precipitation required higher pH levels, indicating the need for sequential treatment to achieve high selectivity. The modeling results further validated the experimental data, confirming the influence of pH, reagent concentration, and ionic strength on precipitation efficiency. The graphical analysis, including identification of peak and valley points, helped visualize the kinetics and equilibrium states of the system. These insights provide a scientific basis for optimizing industrial processes aimed at mineral extraction, water softening, and environmental applications. Moreover, the use of ammonium bicarbonate offers additional advantages due to faster reaction rates and minimal solid waste generation. Future studies should explore scale-up possibilities and integration with continuous processing technologies.

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