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Thermal process to transform silicate minerals into alkaline solids for carbon removal

Stanford researchers in the Kanan Lab have developed a scalable method for achieving verifiable, safe, and permanent carbon removal at relatively low energy demand.

This work demonstrates that calcium oxide can react with diverse magnesium silicates to form calcium silicate and magnesium oxide. When exposed to air and moisture, these products convert to dissolved bicarbonate ions or carbonate minerals, sequestering CO2. By cycling this chemistry with calcium carbonate calcination, a new carbon dioxide removal process emerges where the calcium/magnesium products capture CO2 from air as stable (bi)carbonates while process emissions are sequestered.

Studies shows this could provide efficient CO2 removal using less than half the energy of leading direct air capture technologies. If applied to soils, the calcium silicate/magnesium oxide materials could provide agronomic value as a silicon fertilizer. The process unlocks magnesium silicates as an abundant resource for safe, permanent atmospheric carbon removal with co-benefits.

Stage of Development

- Demonstrated the chemistry with several examples on the kilogram lab scale
- Continued research to scale up from lab-scale to pilot-scale experiments and evaluate applications in soil and other open systems.

Applications

- **Large-scale removal of CO2 from the atmosphere** (carbon dioxide removal or CDR)

- Agronomic input to provide plant-available silicon and soil pH adjustment
- Can provide **high quality carbon offsets** that could be purchased by any company or other entity that seeks to offset their GHG emissions or contribute to CO2 drawdown
- **Safe and permanent sequestration of captured CO2** as stable dissolved bicarbonates or carbonate minerals

Advantages

- **Much lower energy requirements** compared to leading direct air capture (DAC) technologies (less than half the energy per ton of CO2 removed)
- **Produces stable and environmentally benign carbonate minerals** for CO2 sequestration
- **Utilizes abundant magnesium-rich silicate rocks** as a vast feedstock resource
- **Verifiable and permanent removal of CO2** from the air
- Potential to improve crop yields and resistance to pests

Publications

- Chen Y, Kanan M. Thermal Ca^2+/Mg^2+ Exchange Reactions to Transform Abundant Silicates Into Alkaline Materials for Carbon Dioxide Removal. ChemRxiv. 2024; doi:10.26434/chemrxiv-2023-wvwv9-v2

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