Carbon Dioxide Sequestration

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Human activity and CO_2 releases

- We live an energy- rich lifestyle and moreover are “hooked” on fossil fuel sources of energy
- Other sources, such as nuclear, wind, wave and tidal, hydro, solar, geothermal.... all have some undesirable features, e.g., intermittency.
- They are inconsistent with a “push button” approach to supply
- As pragmatists, we concentrate on **mitigation**

Addressing the challenge.

- We address the challenge in the construction sector. The work is supported by **GORD (Gulf Organisation for Research and Development)** and embraces a holistic approach, including energy required to live and work , as well as eventual demolition and re-use of materials.

Concept -1

- Capture and convert CO_2 to stable and useful solids.
- $Mg(OH)_2$ has been obtained from sea water for a century simply by raising the pH. CO_2 is often uptaken during precipitation. Calcination to ~500°C gives MgO.

  - But this has not proven to be a satisfactory low energy process and MgO is not, in our view, a good starting point for materials development.

Instead , we precipitate magnesium hydroxycarbonate hydrates (MHCH phases)

<u>Prospects for decarbonising our lifestyle</u>

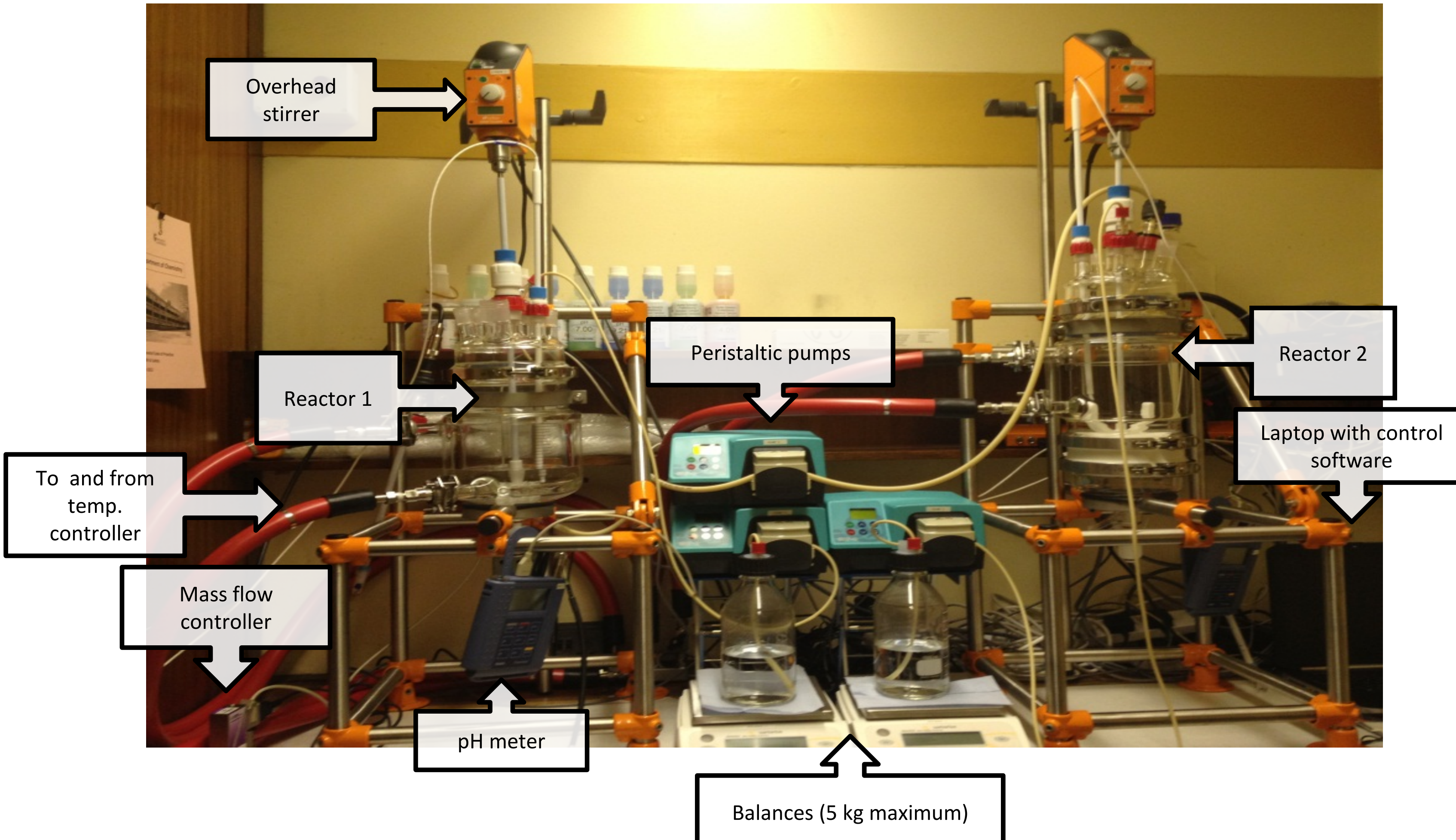
- Increase photosynthesis: fix more carbon
- Sequester carbon in various ways, *e.g.*, CO_2 pumped underground (passive storage)
- **Convert CO_2 to useful solids by organic and <u>inorgani</u>c routes.**
- *Eventually, decarbonate society*

Preparation of MHCH phases

MHCH phases are best made by a two stage process.

1. Dissolving CO_2 in slightly alkaline solution at 1 bar pressure, ~10-50*C
2. Mixing the CO_2 -containing solution with a second solution containing Mg and collecting the MHCH precipitate

Reactor for MHCH Synthesis



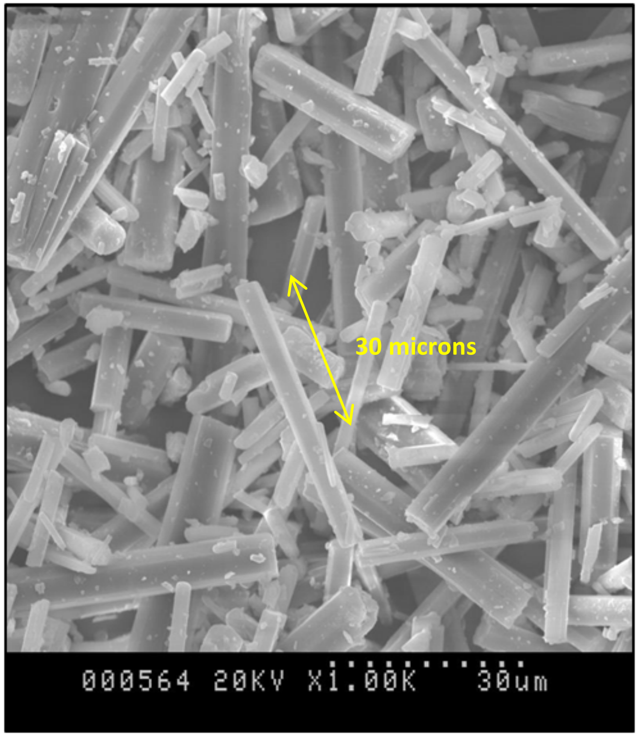
Reactants

- The Mg source is typically reject water from a desalination plant using sea water intake. We use a simulate with ~1M NaCl and ~0.1M Mg
- CO_2 comes directly from a fixed source, such as exhaust gas from a power plant or a cement works but is conveniently modelled using tank CO_2.

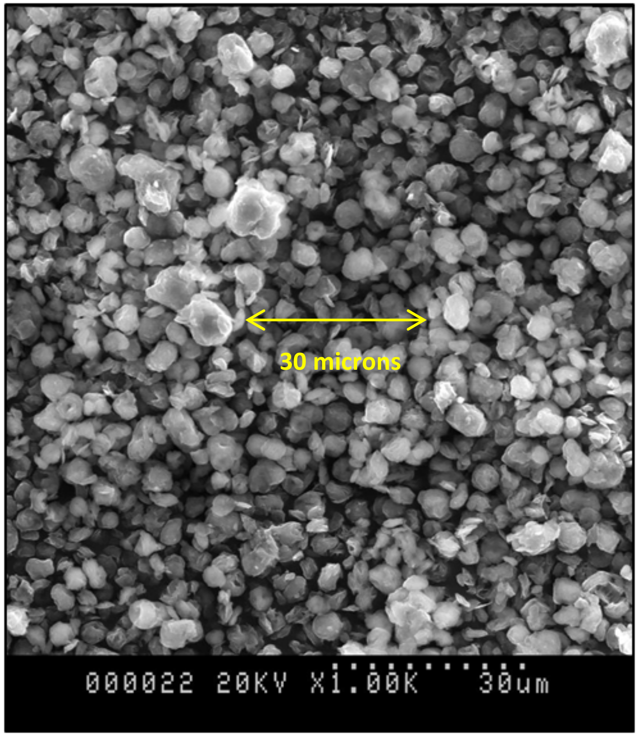
Products

- The preferred solid products are mainly hydromagnesite, $Mg_5[(OH)_2|(CO_3)_4|.4H_2O]$ and nesquehonite, $Mg[CO_3].3H_2O$
- Both occur in nature, hence the mineral names: their crystal structures are known
- Numerous other phases occur in nature, only a few of which are known as synthetics

Products

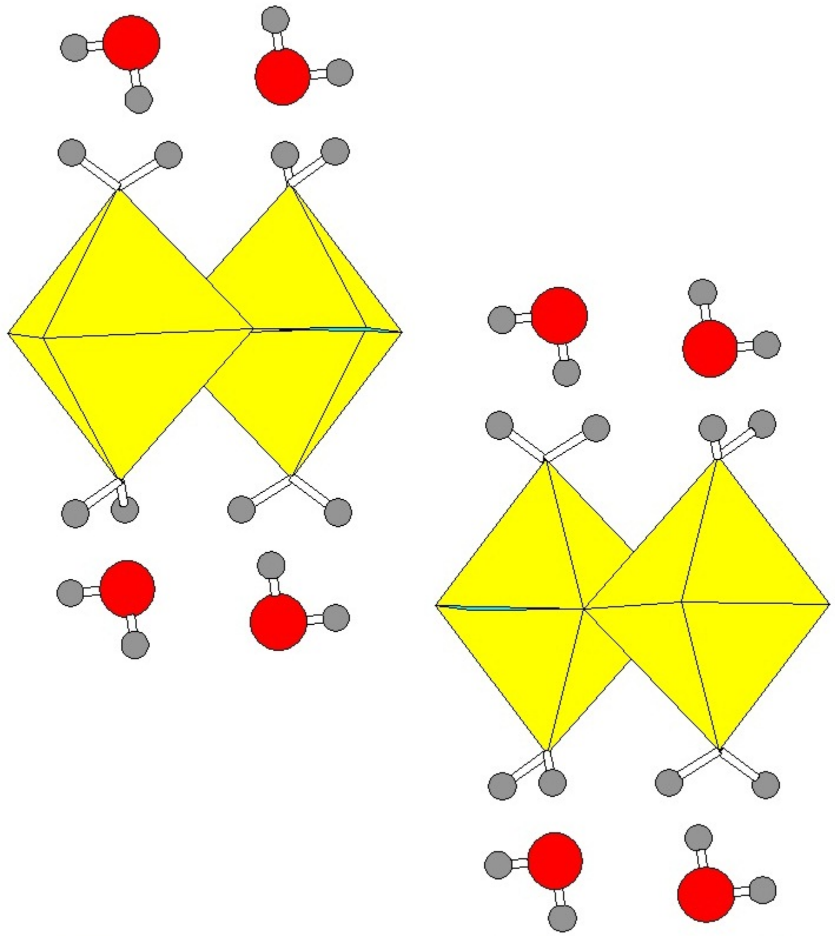


Nesquehonite needles at 1000x magnification

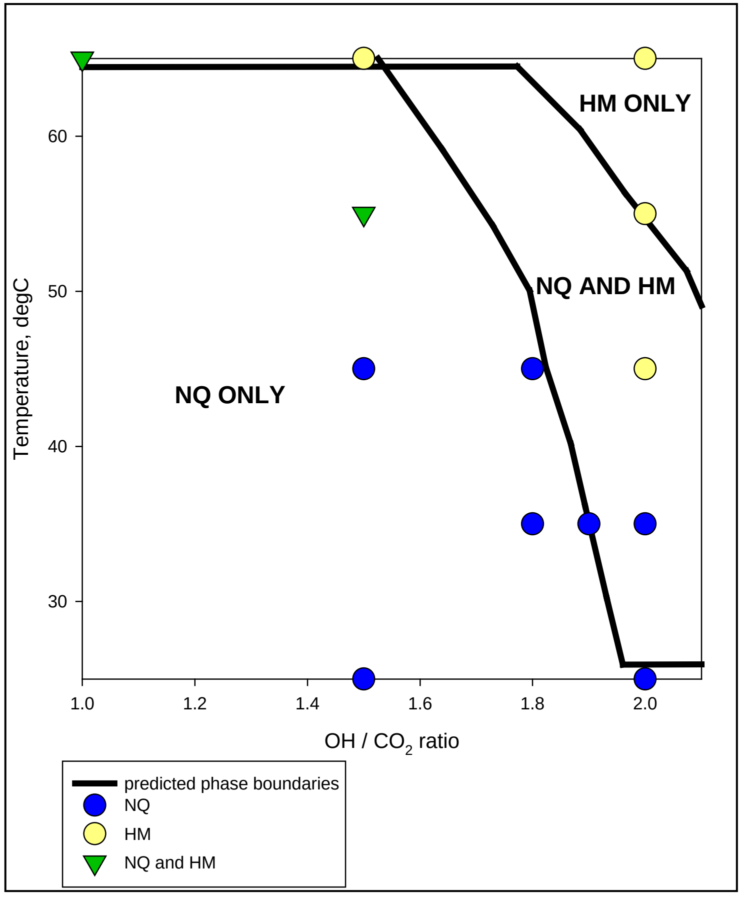


Hydromagnesite grains at 1000x magnification

Structure of Nesquehonite , $MgCO_3.3H_2O$

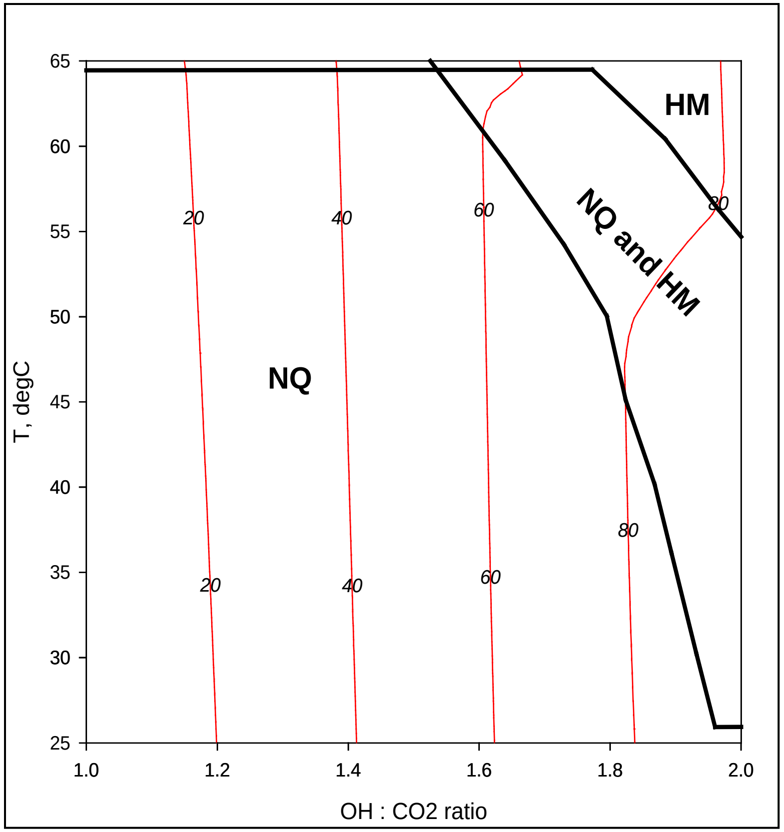


Specimen Calculations



Modelled phase diagram showing experimental points of phase precipitation

Specimen Calculation



Phase Diagram predicted by GEM over a range of temperatures and OH : CO_2 ratios, showing magnesium recovery contours

Calculation *vs* experiment

- Thermodynamic calculations are not necessarily completely reliable and require experimental verification. *Example, metastable formation of dypingite in place of hydromagnesite*
- Nevertheless, calculation greatly shortens the time taken to explore the impacts of changing temperature, species activities, concentrations, etc.
- *Example: calculation of the impact of increasing NaCl salinity on yields has proven surprisingly accurate.*

Product Properties

Properties of self-cemented NQ

- Thermal conductivity: ~ 0.21 $W.m^{-1}.K^{-1}$
- Compressive strength: ~ 5 MPa
- Bulk density: ~ 0.75 $g.cm^{-3}$
- Density of nesquehonite: ~ 1.84 $g.cm^{-3}$
- Porosity: ~ 59 %

Next steps

- Convert reactor to semi- continoous operation
- Make larger (kg) batches for property measurements and property-structure correlations
- Continue process optimisation by combining experiment and calculations
- Develop new applications / products

Conclusions

- We see prospects for converting CO_2 to a useful product containing (as for NQ) 32% carbon dioxide.
- Product is non- toxic, fire retardant and at end of life, easily recycled.
- Carbon capture to form useful engineered materials is a very real prospect