12.085 Seminar in Environmental Science
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Lisa Song
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12.085 Homework 10

Another approach to synthesizing carbonates is to use aqueous chemistry rather than direct carbonation. Although there are more steps involved in this method, the kinetics are more favorable. The basic idea is to extract Mg or Ca from rocks using acid:

$$6HCl + Mg_3Si_2O_5(OH)_4 \rightarrow 3MgCl_2 + 2SiO_2 + 5H_2O \quad (1)$$

Magnesium chloride exists in solution, and is decomposed (through heating) to regenerate HCl:

$$MgCl_2 \cdot 6H_2O \rightarrow Mg(OH)Cl + HCl + 5H_2O \quad (2)$$
$$Mg(OH)Cl \rightarrow Mg(OH)_2 + MgCl_2 \quad (3)$$
$$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O \text{ (direct carbonation step)} \quad (4)$$

In addition, the $MgCl_2$ generated from step 3 can be re-used in step 2 to recover HCl. One advantage of the process is that step 4 releases heat which can be cycled back to other steps of the overall reaction. Step 3 is also used industrially for producing $Mg(OH)_2$, so the infrastructure for the reaction already exists. (Blackburn and Nagamori, 1994; Lackner et al., 1995).

Like last week, I had problems finding actual reaction rate kinetics; the articles I read mainly focused on thermodynamic analyses. One critique of the system is that step 2 is highly endothermic due to the energy required to release water, but the step is necessary because it's not practical to use HCl continuously without recycling it. A solution has been proposed to use $MgCl_2(H_2O)$ instead of HCl for dissolving rocks; reducing the water content would speed up the process and decrease the energy needed to run the reaction. However, this solution is also flawed since $MgCl_2(H_2O)$ is less acidic than HCl, and may not be acidic enough to dissolve the rocks (Eliasson et al., 1999).

References:

Blackburn, D. and M. Nagamori (1994), Slurry filtration and cake washing after the HCl-leach of magnesite and serpentine—continuous washing model, *Metallurgical and Materials Transactions B,* 25:3, 321-331.

Eliasson, B. et al. (Eds.) (1999), *Greenhouse Gas Control Technologies,* Elsevier.

Lackner et al. (1995), Carbon dioxide disposal in carbonate materials, *Energy,* 20:11, 1153-1170.