

TITLE: Geochemical studies of CO₂-Brine-Rock interaction at surface and subsurface conditions during geological storage of carbon dioxide

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ABSTRACT

To support effective geological CO₂ capturing and storage design and operations, the dissolution and precipitation of the CO₂-Brine-rock system were simulated to investigate the chemical interactions within the system concerning the effect resulted from change in their thermodynamics properties. Geochemical models were built using PHREEQC software to represent surface, injectivity and subsurface conditions. Brine rich in magnesium and calcium ions (Mg²⁺ and Ca²⁺) collected from desalination plant were reacted with CO₂ and supercritical CO₂ (scCO₂) to form carbonates. The initial model created are CO₂ + Brine and scCO₂ + Brine reaction buffered with NaOH, also, their reaction with formation water as well as their interaction in formation rock were equally modelled. The chemistry of the aqueous solutions for the models are then investigated in terms of CO₂ (mol/kg) dissolution, specific conductance (μS/cm, °C), Density (g/cm³), Pe (charges), and pH with respect to changes in temperature, pressure, CO₂ Concentration, and ion concentration (Mg²⁺ and Ca²⁺) at surface and subsurface conditions.

The results show that, scCO₂ increases the reactivity of the aqueous species as well as enhances the dissolution of components to form insoluble carbonate minerals. Base pH 8 reduction was observed in all case but more in scCO₂, Also Pe was uniform at 4 in surface condition, but fluctuation was observed as CO₂ reacts in aquifer with a range from 0 – 12, and -0.2 – 4 for scCO₂ reaction in aquifer. At high temperature specific conductance increase by more than 50% in surface condition compared to pressure, pH and CO₂ concentration. The fluid chemistry showed that the concentration Ca, Mg and K increase with time due to the dissolution of rock minerals such as K-Feldspar, Calcite etc. On the other hand, the release concentration of Al, Si and Fe ions decrease with time due to the precipitation of secondary minerals such as Dawsonite, Muscovite, Clinochlore, Kaolinite, Magnetite, Gibbsite and others.

The order of dissolution and precipitation of the reacting components using calcite as a case study was observed with the Kinetic model of PHREEQC predicted the dissolution of calcite for 50 years. Calcite dissolves in less than one year at high temperature above 80°C and dissolve gradually to precipitate secondary minerals within 50 years at temperature below 80°C. The precipitation of secondary minerals confirms the chemical reactivity of the aquifer to precipitate minerals that can serve as an impermeable seal for long term confinement of CO₂.

Keywords: CO₂ mineralization, CO₂-Brine-Rock Interaction, Formation water, Geochemistry, Mg/Ca Ratios, CO₂ geological storage