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### **Title**

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## **CO<sub>2</sub> Geological Sequestration**

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Human activities are increasingly altering the Earth's climate. A particular concern is that atmospheric concentrations of carbon dioxide (CO<sub>2</sub>) may be rising fast because of increased industrialization. CO<sub>2</sub> is a so-called "greenhouse gas" that traps infrared radiation and may contribute to global warming. Scientists project that greenhouse gases such as CO<sub>2</sub> will make the arctic warmer, which would melt glaciers and raise sea levels. Evidence suggests that climate change may already have begun to affect ecosystems and wildlife around the world. Some animal species are moving from one habitat to another to adapt to warmer temperatures. Future warming is likely to exceed the ability of many species to migrate or adjust. Human production of CO<sub>2</sub> from fossil fuels (such as at coal-fired power plants) is not likely to slow down soon. It is urgent to find somewhere besides the atmosphere to put these increased levels of CO<sub>2</sub>. Sequestration in the ocean and in soils and forests are possibilities, but another option, sequestration in geological formations, may also be an important solution. Such formations could include depleted oil and gas reservoirs, unmineable coal seams, and deep saline aquifers. In many cases, injection of CO<sub>2</sub> into a geological formation can enhance the recovery of hydrocarbons, providing value-added byproducts that can offset the cost of CO<sub>2</sub> capture and sequestration.

Before CO<sub>2</sub> gas can be sequestered from power plants and other point sources, it must be captured. CO<sub>2</sub> is also routinely separated and captured as a by-product from industrial processes such as synthetic ammonia production, H<sub>2</sub> production, and limestone calcination. Then CO<sub>2</sub> must be compressed into liquid form and transported to the geological sequestration site. Many power plants and other large emitters of CO<sub>2</sub> are located near geological formations that are amenable to CO<sub>2</sub> sequestration.

### *Mechanisms for CO<sub>2</sub> Trapping*

Carbon dioxide is retained in geological formations in three ways. First, CO<sub>2</sub> can be trapped as a gas or supercritical fluid under a low-permeability caprock. This process,

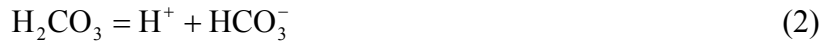
commonly referred to as hydrodynamic trapping, will be, in the short term, the most important method of retention. Second, CO<sub>2</sub> can dissolve into the groundwater, a process referred to as a solubility trapping. The latter increases the acidity of the groundwater and increases the solubilities of many minerals composing the host rock. Third, CO<sub>2</sub> can react directly or indirectly with minerals in the geologic formation leading to the precipitation of secondary carbonate minerals. This so-called “mineral trapping”, is potentially attractive because it could immobilize CO<sub>2</sub> for very long periods of time.

#### *Reaction Activities*

First, CO<sub>2</sub> dissolves in water to produce the weak carbonic acid:



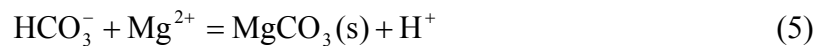
This is followed by rapid dissociation of carbonic acid to form the bicarbonate ion:



The increased acidity induces dissolution of many of the primary host rock minerals, which in turn causes complexing of dissolved cations with the bicarbonate ion such as



The dissolved bicarbonate species react with divalent cations to precipitate carbonate minerals. Formation of calcium, magnesium, and ferrous carbonates are expected to be the primary means by which CO<sub>2</sub> is immobilized.



### *Research History*

The feasibility of sequestering CO<sub>2</sub> in deep geological formations has been discussed in scientific studies over the last decade. These studies include an evaluation of the potential of CO<sub>2</sub> saline aquifer storage in The Netherlands and in the Alberta Basin, Canada. Moreover, the large-scale injection of CO<sub>2</sub> has already been carried out in the Norwegian sector of the North Sea. The potential of CO<sub>2</sub> geological sequestration has prompted a number of laboratory and field experimental studies in Europe and North America. Computer modeling of these processes is also necessary to evaluate long-term CO<sub>2</sub> injection, because aluminosilicate mineral alteration is very slow under deep subsurface conditions. The experimental and computer modeling studies are complementary, and the former provides data for the validation of the latter.

### *Further Research Needed*

Even though CO<sub>2</sub> geologic sequestration appears feasible, further research is needed before this option can be fully implemented. First, scientists need to identify sequestration sites and assess the capacities of geological formations. In addition, they need to develop monitoring technologies to assure the public that the CO<sub>2</sub> can be stored safely - this may be the most important objective of all. In addition, improvements in computer simulation models for predicting the performance of CO<sub>2</sub> geological sequestration are needed. Scientists are also looking for ways to lower the overall cost of geological sequestration by improving the technology for CO<sub>2</sub> capture. If they learn that some less-pure CO<sub>2</sub> waste streams (such as those containing H<sub>2</sub>S and/or SO<sub>2</sub>) can enhance the sequestration process, or at least not interfere with it, the cost of separating CO<sub>2</sub> from a coal gasification or power-plant flue gases may drop dramatically.

