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Preliminary experiments for a chemical reactive barrier as a leakage mitigation technology

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Abstract

Carbon capture and storage (CCS) risk assessments have proposed technologies to remediate carbon dioxide (CO_2) leakage. One of these technologies utilizes an alkaline silicate solution forming a chemical barrier when mixed with CO_2-enriched water. This study characterizes the physical properties of the silicate solution and the formation of the chemical barrier in a small-scale flow-through experiment. Results show that barrier formation using the silicate solution is effective as a drop in permeability by one order of magnitude is observed in our preliminary experiments. These preliminary results will be used for the design of future core-flood experiments and reactive-transport modelling.

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Keywords: CO_2 leakage; remediation technologies; sodium silicate; chemical barrier formation

1. Introduction

During the last decade, carbon capture and storage (CCS) has been developed as a new technology to mitigate carbon dioxide (CO_2) emissions. The IPCC [1] states that one of the main concerns of CO_2 storage is the possible migration of CO_2 through different pathways. In order to improve risk management options a number of technologies and materials have been proposed to mitigate and remediate CO_2 leakage [2].

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In order for these technologies to be operational, they need to account for CO_2 storage reservoir conditions including pressure, temperature and water composition. Of particular importance is the mildly acidic pH (pH=4) of the formation water when enriched with CO_2. The application of some of the proposed technologies such as cement formation [3] or biomineralization of carbonates [4] is limited because their final sealing products are reactive under acidic systems. Essentially all lime- and carbonate-based barriers are prone to dissolution in contact with acidic water.

To overcome this problem some studies have proposed the formation of a chemical barrier that is chemically stable in an acidic environment [5, 6]. These studies proposed the use of an alkaline sodium silica (Na-Si) solution as a chemical reagent that reacts with CO_2-enriched water. The reaction leads to a precipitate that fills the pores of a high permeable zone. Thus, the reaction will create a barrier that seals the leakage by reducing the permeability.

The alkaline Na-Si solution leads to the precipitation of an amorphous silica phase in contact with a CO_2-enriched solution and the precipitate is stable under acidic and pH neutral conditions. In this case the precipitation is triggered by a change in pH. The mixing of the acidic CO_2-enriched solution with the alkaline Na-Si solution results in a pH neutral to mildly alkaline solution triggering the formation of amorphous silica. This behaviour is illustrated in a stability diagram for sodium silicate (Fig. 1), modelled in Geochemist's Workbench (GWB) under CO_2 storage conditions with a temperature of 60°C and a pressure of 140 bars.

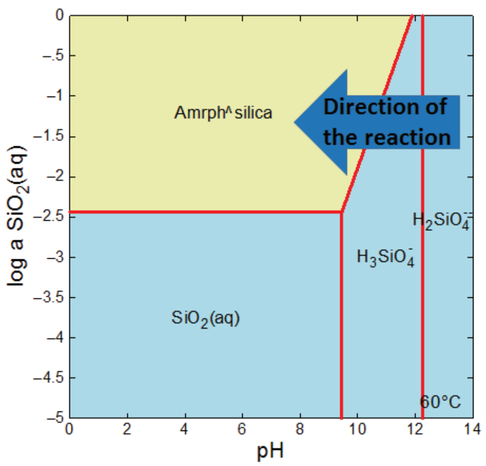

Fig. 1. Activity diagram of aqueous silica with a representation of the proposed mixing of fluids leading to the precipitation of amorphous silica.(T= 60°C, P= 140 bars)

Based on the chemistry of sodium silicate, Ito, et al [5] performed a batch experiment using synthetic material. They also simulated the reaction using a reactive transport model. Their results showed that precipitation of amorphous silica and permeability reduction, were possible. However, changes in parameters such as concentrations, viscosities and reaction in a natural rock sample were not taken into account. Since this technology is currently at an evaluation stage, further process studies under well-defined laboratory conditions are needed.

Several characterization and experimental tests have been carried out as part of this study in order to develop a better understanding of the reaction under variable conditions. Firstly, we measured physical and chemical properties of the Na-Si solution at different concentrations, and secondly, we set up a small-scale flow-through experiment to observe the formation of the silica barrier. This paper presents the preliminary characterization and experimental results using alkaline Na-Si solution as a chemical reagent for the development of a barrier formation technology to remediate CO_2 leakage.