The fate of co-injected impurities and the impact of CO_2 quality on the near well-bore behaviour and injectivity

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ABSTRACT

Carbon dioxide capture and storage (CCS) is a developing technology to reduce greenhouse gas emissions and address climate change. An important but not very well studied aspect in the analysis of CO_2 storage is the quality requirements on stored CO_2. Depending on the industrial (energy production, iron industry, concrete production, etc.) and capture processes, the composition of the gaseous mixture will considerably vary in nature and concentration. The degree of purity of the captured CO_2 is thus a key factor for transportation, injection and sequestration. In addition to CO_2 and traces of water, other gases, such as O_2, N_2, SOx, NOx, H_2, CO, H_2S, will be present in various amounts. These gases issued from industrial and capture processes are still poorly studied in the framework of geological storage technologies, but they are a main issue because they affect the compressibility of the injected CO_2 and reduce the storage capacity in free phase. Additionally, depending on the type of geological storage (saline aquifer, depleted gas reservoir, etc.), the presence of ancillary gases may also have other specific effects. In the case of CO_2 storage in deep saline formations, the presence of gas impurities affects the aqueous solubility of gases and the rate and amount of CO_2 storage through mineral dissolution and precipitation. Hence, precise data are needed on the range of gas compositions other than pure CO_2, because although there are environmental issues to address, the co-storage of CO_2 and contaminants could save costs.

The behaviour of CO_2 and co-injected gases in reservoirs can only be forecasted through numerical modelling. However, the modelling of gas mixtures and their impacts on different rock types (mineral assemblage from reservoir, cap-rock and well-bore completion) under various pressure and temperature conditions is currently still a challenge. These numerical simulations are most commonly based on an accumulation of approximations because of i) the lack/scarcity of thermodynamic data and EOS parameter values for the gas mixtures, and ii) the current equations of state for complex gas mixtures are not yet reliable.

In this study, numerical simulations are used to analyse the impact of CO_2 quality on the injectivity and the near well-bore zone of both a deep saline aquifer and a depleted gas reservoir. The chemical reactivity of both systems with respect to CO_2 and SO_2 injections is expressed in terms of porosity variations. The intensity of the porosity decrease in the deep aquifer is greater than in the depleted gas field, showing a stronger reactivity of the aquifer. A higher dissolution of injected gaseous species is expected in the deep saline aquifer compared to the depleted gas field due to the higher pressure and lower temperature conditions in the former. According to SO_2 concentrations in the gas phase, sulfate minerals are expected to precipitate in the saline aquifer, which could lead to possible risks of decreasing injectivity. This phenomenon of mineral precipitation in the near-well zone, identified for elevated SO_2 concentrations in the gas mixture, is a key point to consider.

Another important point concerns the well completion, in particular the materials involved: cement and steel. Besides the well-known carbonation process, i.e. the chemical alteration of cement by CO_2, the presence of SO_2 in the injected gas leads to a sulfatic attack of the

cement. These reactions could alter the sealing character of the materials and therefore create pathways for leakage. The present study modelled the effect of $CO_{2(g)}$+$SO_{2(g)}$ on the mineralogy and porosity of a well cement.

We also analysed the impact of an effluent gas issued from oxycombustion capture (containing SO_x, NO_x and O_2) in case of leakage into a shallow aquifer. These gas components can potentially generate sulfates, nitrates and nitrites that can pose a health problem to drinking water and must thus not exceed authorised maximal concentration levels. We modelled the chemical evolution of drinking water from the Paris Basin following the progressive dissolution-reaction of CO_2-rich gas containing SO_x, NO_x and O_2. Some health-sensitive solute concentrations were compared with their maximal concentration levels.

Finally, these numerical simulations demonstrate that the injection of CO_2 with associated gases leads to highly reactive systems inducing a dramatic mass exchange between phases (rock minerals – brines – supercritical CO_2 +(reactive impurities as SO_2 and O_2)) for both carbonate and sandstone deep saline aquifers. Porosity has a complex pattern in the near well-bore zone showing opposite phenomena, such as massive dissolution of carbonates and possible precipitation of sulfates.

These general results highlight the reactivity (fate/impact) of CO_2 co-injected impurities and the need to consider these gases in numerical simulations. In order to perform accurate predictions, different key points have to be studied:

- Compilation/analysis of new data on gas solubilities in saline waters (i.e. salting out and temperature effects, etc.) and also the EOS of targeted mixes (CO_2 + co-injected gases).
- Temperature effect in order to integrate the antagonist behavior (prograde for aluminosilicates and retrograde for carbonates and sulfates) and the hydrodynamic / transport effects.
- Analysis of different injection scenarios in order to explore the sensitivity of key parameters and to establish specific relationships between Flow Rate-Pressure-Temperature-time (Q – P – T – t).

Keywords: Numerical modeling, impurities, well completion, near well-bore, PVTx, EOS.

Proposed Topic: CO_2 Storage: Impact of the Quality of CO_2