



CO₂-Storage Simulation with regard to Cold Hydro-Fracturing and Vaporization/Condensation

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The simulation of the process of CO₂ storage in porous media requires the solution of the coupled system of differential equations of multiphase flow, transport of CO₂ in liquid and gaseous (supercritical) conditions and other gases, transport of dissolved CO₂ in water and transport of energy (temperature). Therefore, the implementation of the thermodynamic phase behaviour of CO₂ in all possible options is necessary. Moreover, the chemical reactions between CO₂ and rock material should be considered.

The main aim of developing inhouse simulation software Mod2Phase was to include the enthalpy behaviour, and pressure- and temperature dependent phase behaviour during the injection of cold liquid CO₂ in deep and high temperature formations. With the new simulation software Mod2Phase-thermo the stimulation of low permeable and deep formations of Pre-Zechstein can be simulated, which will consider the high pressure – low-temperature effects during CO₂ (liquid) injection. The required temperature reduction is expected to be about 100 K.

All differential equations will be solved numerically using balance method in 3D-cartesian coordinate system. The flow- and transport-equations might be solved individually or if necessary by iteration. The required time step control is based on physical background (3D-Courant-condition) referred to Picard-Iteration and is depending on the solvability of the equation system using Newton-Raphson-Iteration.

All relevant thermodynamic data of CO₂ and water involved are integrated in the software. In relation to pressure and temperature the phase change of CO₂ from liquid to gas, and from liquid to supercritical, respectively will be considered in capillary effects, change of saturation, concentration and temperature (evaporation-enthalpy).

The software has the option at a given time to access the geochemical software PhreeqC. An iteration of geochemistry and transport is not necessary due to different time-scales.

For the validation of the software Benchmark-Tests [Class et al., 2009] were simulated. The obtained results showed a good match with the published results. The software Mod2Phase was implemented in a study for a Pre-Zechstein CO₂-Storage and for fundamental investigations of cold-hydro-fracturing with liquid CO₂ in CO₂-storage, in geothermal reservoirs with low permeability and in tight-gas-formations.