

Kinetics of the abiotic oxidation of hydrogen (H₂) by hematite at subsurface storage conditions

THEODOR ALPERMANN¹,
CHRISTIAN OSTERTAG-HENNING^{1*}

¹Federal Institute for Geosciences and Natural Resources,
30655 Hannover, Germany
(*correspondence: Christian.Ostertag-Henning@bgr.de)

The production of hydrogen from excess electricity provided by renewable sources combined with underground storage of hydrogen is one promising approach to buffer seasonal fluctuations of renewable electricity production. The storage operation in a porous reservoir can be influenced by geochemical reactions if they affect processes like significant loss of H₂, quality deterioration by reactions producing gaseous (e.g. H₂S), loss of injectivity/productivity by decreased permeability or induced two phase-flow in the reservoir and leakage of H₂ through the cap rock.

For reliable assessment of the influence of geochemical reactions quantitative data on reactions and reaction kinetics are crucial. Our work is focussing on the determination of kinetic data for abiotic redox reactions of hydrogen with iron- and sulfur-containing minerals in reservoir rocks (e.g. hematite, Fe-containing clay minerals) and in cap rocks (e.g. pyrite).

Here we present results of experiments with molecular hydrogen and fine-grained hematite. The experiments were conducted in sealed gold capsules within high-pressure autoclaves at subsurface storage conditions (70 – 120°C; 10 MPa H₂). The reaction of the oxidation of H₂ by hematite was followed by gas analysis (gas chromatography and mass spectrometry) as well as quantitative x-ray diffraction analyses of the obtained solid reaction product.

Hydrogen was completely oxidized within four days even at 90°C. Magnetite is the only solid reaction product in the initially dry system, significant amounts of water formed as oxidation product of H₂. Magnetite was formed as idiomorphic substitution after hematite as well as in the form of octahedral crystals indicating a coupled dissolution-reprecipitation mechanism enabled by the generated reaction water. An activation energy of ca. 91 kJ/mol for molecular hydrogen oxidation by hematite was calculated, which is in good agreement with previously reported values [cf. 1]. The kinetic data of the hematite-hydrogen system along with results from other mineral-hydrogen experiments provide valuable input data for future modelling of geochemical processes during the subsurface storage of hydrogen.

[1] Lu & Tsai (2015) *RSC Adv.* **5**, 17236-17244.