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Geochemical reactions of iron oxides with hydrogen in the porespace of sandstones: Processes, kinetics & limitations of the extent of reaction.

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Over the last years the interest in molecular hydrogen (H₂) has soared: in many countries an accelerating energy transition is considering hydrogen as the main energy carrier of the future. To enable large scale storage for hydrogen, research on subsurface storage options in geologic structures as artificially created caverns in evaporites (e.g. salt domes) or depleted gas fields mainly in sandstones is pivotal. Some countries as Germany have large volumes available in existing and additionally mineable caverns being the preferred option, but many regions in Europe will continue to use porous rocks –and there mainly sandstone reservoirs of depleted natural gas fields –as underground storage option. In these sandstones geochemical reactions of the molecular hydrogen with dissolved ions in the pore water –and foremost –on reactive mineral surfaces have to be considered in risk assessments for selecting the most suitable rock formations. Some minerals may oxidize hydrogen resulting in a loss of hydrogen and the production of either water or hydrogen sulfide. These products may enhance the alteration of the rock by increasing dissolution-precipitation reactions –or impart on the recoverable gas quality e.g. by traces of hydrogen sulfide (Heinemann et al. 2021).

In this contribution the results from geochemical experiments at in situ conditions (elevated pressures and temperatures as in the subsurface in presence of a liquid water phase) of one common reactive mineral in many sandstones –the iron oxide hematite Fe₂O₃ –will be presented. The discussion will focus on details on the processes observed, the kinetics of the overall oxidation of hydrogen by hematite, and parameters limiting the extent of the oxidation of hydrogen. An interesting link to ongoing research results in photo(catalytic) water splitting on hematite surfaces has emerged during the study. In addition, for a set of five different natural sandstone samples from the Bunter formation with different contents of hematite the extent of the reaction was investigated over one month at a pressure of 120 bars and a temperature of 120°C. The overall oxidation of hydrogen was low, but significant differences were apparent between the rocks. Spatially resolved analyses by optical microscopy and Raman spectroscopy allowed to document the reaction products in the intact pore space in the sandstones during and after experiments, pointing to mineral matrix effects on geochemical reactions and hence changes in porosity, pore throat diameters and permeability. These findings will help in delineating guidelines for selecting the formations best suitable for storing hydrogen for extended times in subsurface sandstone reservoirs.

Participation

In-Person

References

Heinemann et al. (2021): Enabling large-scale hydrogen storage in porous media –the scientific challenges. – Energy Environ. Sci., 2021,14, 853-864.

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