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A micro-scale analysis for wettability characteristics of H2 in heterogeneous geological media

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Underground Hydrogen Storage (UHS) has the potential to play an important role in the transition towards renewable energy resources [1,2]. In many industrial applications, initially a mixture of hydrogen (H2) and methane (CH4) will be introduced to the grid and storage facilities [3]. Secure and efficient UHS requires accurate characterization of the cyclic movement of the H2-CH4 gas mixture through the reservoir which highly depends on the wettability of the system [4].

To get a better understanding of the wettability behavior of cyclic stored H2-CH4 gas mixtures, and the factors that contribute to contact angle hysteresis, we measure intrinsic contact angles and dynamic contact angles during drainage and imbibition, for H2, CH4 and their mixtures, in contact with brine under a range of pressure, temperature and salinity conditions using the captive-bubble cell approach [5,6] and microfluidics approach [7], respectively. The microfluidic experiments allow us to look at the impact of different heterogeneity structures on the contact angle hysteresis, while the captive-bubble cell approach is used to investigate the impact of pinning. In the captive bubble cell method, the rock sample (Bentheimer) is placed in a high P, T cell, filled with brine. Gas bubbles are released from the bottom of the cell and buoyantly rise through the brine until they reach the rock surface. The gas bubbles slowly dissolve into the brine while images are taken every minute. The images are processed with our in-house code to calculate the contact angles. The captive bubble cell approach is traditionally seen as static measurement, however, due to the dissolution of the gas into the brine the bubble size decreases with time. This dynamic behavior is mimicking the imbibition process where water is displacing the non-wetting phase and allows for the visualization and the characterization of the effect of pinning on the contact angle.

Our preliminary results show that pinning can significantly increase the contact angle and more pinning is observed in the higher salinity brines. Furthermore, no contact angle hysteresis is observed in homogeneous micro-fluidic systems. Overall, H2, CH4 and their mixtures, show similar wettability behavior independent of pressure, temperature and salinity. To further explore the observed behavior, a theoretical analysis based on the Young-Laplace equation is carried out for the captive-bubble cell method. This analysis shows that the contact angle depends on 1. the density difference between the brine and the gas, 2. the interfacial tension and 3. the bubble radius, of which the combined effect can be characterized with the Bond number. Moreover, we theoretically validate that under similar Bond numbers and similar bubble radii, the contact angles of H2 and CH4 bubbles and their mixtures are indeed comparable. Our work suggests that in real field processes in which buoyancy and capillary are the main acting forces, H2, CH4 and their mixtures, will have similar wettability behavior independent of pressure and temperature. More details about this part of the work can be found in the journal manuscript [6].

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

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