Contribution ID: **615** Type: **Poster Presentation**

Capillary sealing efficiency of caprock: Implications for hydrogen and carbon-dioxide geo–storage

Monday, 30 May 2022 15:10 (1h 10m)

Geo-storage of hydrogen (H_2) and carbon dioxide (CO_2) is a promising solution for a low-carbon global economy (Ali, 2021; Ali et al., 2022a; Ali et al., 2021b; Bui et al., 2018; Pan et al., 2021b). The knowledge of the capillary entry pressure of caprock is critical, which provides a rapid assessment of the capillary sealing efficiency and sealing capacity, particularly in the presence of impurities (organic acids) and formation brine (Hosseini et al., 2022a; Pan et al., 2021a). However, the literature lacks such analysis on caprock under storage conditions, specifically for H_2. An efficient and safe structural storage requires a deep understanding of key parameters such as pore geometry, organic acid contents, pressure, temperature, and salinity on the wetting characteristics of the rock/gas/brine system for comprehending the capillary sealing efficiency (Al-Anssari et al., 2018; Al-Yaseri et al., 2022; Ali et al., 2020; Ali et al., 2021a; Arif et al., 2019; Hosseini et al., 2022b; Iglauer et al., 2021). Therefore, it is pertinent to determine the wetting characteristics of caprock and interfacial tension (IFT) between liquid and gas to mitigate any potential sealing problems.
The capillary sealing efficiency and entry pressure of the gas is determined using the interfacial tension (IFT) between liquid and gas, the contact angle of the rock surface in the presence of liquid and gas, and the typical pore throat radius of caprock, i.e., 5 nm and 10 nm (Hosseini et al., 2022a). The capillary sealing works against the buoyancy pressure exerted by the gas column height, therefore, the maximum static column height of the gas is crucial in these calculations (Hosseini et al., 2022a; Iglauer et al., 2015). The geological formation contains organic molecules and their effect on wetting characteristics is widely reported (Akob et al., 2015; Ali et al., 2020; Ali et al., 2019a; Ali et al., 2019b; Ali et al., 2021a; Ali et al., 2021b; Ali et al., 2022b; Lundegard and Kharaka, 1994). Therefore, this work investigates the capillary-sealing efficiency using contact angle measurements of pure mica as a proxy of caprock compared to organic-aged mica, and the effect of alumina nanoparticles on organic-aged mica substrates under various geological conditions (i.e. up to 25 MPa and 343 K).
The results indicate that the sealing efficiency and storage capacity for H_2 and CO_2 decreased with pressure and higher organic surface concentration but increased with temperature. The analysis demonstrates the theoretical inverse relationship between the capillary entry pressure and the pore throat radius. The smaller the pore size, the more suitable the conditions for sealing and storage capacity. The analysis of the alumina-nano-organic-aged mica/CO_2 systems showed improved wettability and better sealing efficiency. In a nutshell, this work provides a detailed theoretical workflow to assess the influence of organic molecules on the sealing efficiency and storage capacity of caprock for safe and secure geo-storage of H_2 and CO_2.

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Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

In person

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Session Classification: Poster

Track Classification: (MS01) Porous Media for a Green World: Energy & Climate