Underground Hydrogen storage with CO2 cushion gas in aquifers: Which Equation-of-State?

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Hydrogen is considered a key contributor to the energy transition, provided it is produced from renewables and/or decarbonized. Since this production is estimated to be intermittent as that of renewable electricity, safe storage of large quantities of H_2 needs to be considered. Currently hydrogen storages are operated in salt caverns. However, deep saline aquifers offer medium to very large storage capacities, as well as a wide geographic distribution. Therefore, this work aims to improve the evaluation of the performance and safety of the storage of hydrogen in deep aquifers, in combination with CO_2 and/or CH_4 acting as a cushion gas – CO_2 being stored permanently.

One important challenge is to understand and minimize the degree and extent of the mixing zone between hydrogen and other impurities, or the spreading of the front between these fluids. In fact, the degree and extent of the mixing zone is directly related to the recovery ratio and the purity of hydrogen withdrawal. To that end, simulations require a proper description of the fluid behavior of the different components within the reservoir.

An accurate description of this multi-compositional multi-phase flow requires a robust equation of state that proves to be efficient over a large broad range of temperatures and pressures and particularly around the storage conditions. Herein, we study the different possible thermodynamic models (the research is oriented to cubic Equation-of-State (EoS) and the GERG-2008 equation) and their ability to predict the behavior of compounds of interest separately as well as the possibly resulted mixture. This task is also an attempt to delineate the range of storage conditions, where CO_2 and H_2 may form two separate phases in the mixing zone, or be in the single phase region and then, identify the optimum reservoir conditions, i.e., pressure, temperature and architecture that would rather curtail the mixing phenomena. The choice of the EOS to be adopted is based on the results issued from different EOS compared to the experimental data in the literature and on the limitation of each EOS especially around the mixture critical line. The selected module would be implemented in a simulation research code to examine the flow behavior at reservoir conditions and compare it with industrial simulator output. Using this module, different scenarios will be evaluated to suggest the suitable injection configuration that could possibly limit the occurrence of miscible or immiscible viscous fingering and could control the hydrodynamic stability of the front between fluids.

Keywords: Hydrogen Storage, mixing, EoS, CCS