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Zeta potential of supercritical CO_2-aqueous solution-sandstone systems and its correlation with wettability and residual subsurface trapping of CO_2

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Although CO_2 geological storage (CGS) is thought to be one of the most promising technologies to sequester the anthropogenic CO_2 to mitigate the climate change, implementation of the method is still challenging due to lack of fundamental understanding of controls of wettability, which is responsible for residual trapping of the gas and its flow dynamics. One of the key parameters that controls the wetting state is the zeta potential at rock-water and CO_2-water interfaces. Zeta potential in systems comprising rocks, carbonated aqueous solutions and immiscible supercritical CO_2 have not been measured prior to this study, where we detail the experimental protocol that enables measuring zeta potentials in such systems, and report novel experimental data on the multi-phase macroscopic zeta potential. We also demonstrate for the first time that the zeta potential of supercritical CO_2-water interface is negative with a magnitude greater that 14 mV. Moreover, our experimental results suggest that presence of multi-valent cations in tested solutions causes a shift of wettability towards intermediate-wet state. We introduce a new parameter that combines the multi-phase zeta potential and relative permeability endpoints to characterize the wetting state and residual supercritical CO_2 saturation. Based on these results, we demonstrate that the zeta potential measurements could serve as a powerful experimental method for predicting CGS efficiency and/or for designing injection of aqueous solutions with bespoke composition prior to implementing CGS to improve the residual CO_2 trapping in sandstone formations.