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Minimum miscibility pressure determination in confined nanopores considering the presence of the second liquid phase

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In recent years, tight and shale reservoirs have become increasingly significant in global oil and gas production. However, the recovery efficiency from these reservoirs remains low, with a substantial portion of shale oil left unrecovered. CO2 flooding has emerged as a leading method for enhanced oil recovery (EOR) in these environments, offering both improved oil extraction and opportunities for Carbon Capture, Utilization, and Storage (CCUS), which could help mitigate global warming. A common characteristic of such reservoirs is the prevalence of nano-scale pores. Accurately predicting the Minimum Miscibility Pressure (MMP) of oil and CO2 is vital for the successful implementation of CO2 injection strategies in unconventional reservoirs. However, existing MMP prediction methods are primarily developed for bulk conditions and fail to accurately predict MMP in the nanopores common in tight/shale reservoirs. Furthermore, modeling the oil-CO2 MMP in shale reservoirs is complicated by the frequent occurrence of vapor-liquid-liquid (VL1L2) three-phase equilibria, where the L1 phase represents the heavier liquid phase, and the lighter liquid phase (L2) contains a significant amount of gaseous solvents. The presence of this second liquid phase can significantly affect oil recovery efficiency and CO2 storage capacity due to changes in relative permeability curves and MMP values. This paper presents the development of a comprehensive thermodynamic model that more accurately describes oil-CO2 MMP profiles in tight/shale reservoirs, taking into account the presence of the second liquid phase. A novel MMP calculation algorithm, based on the MMC algorithm, is introduced, incorporating the effects of capillarity, confinement, and the second liquid phase. Example calculations demonstrate the effectiveness and the robustness of the proposed algorithm. The results indicate that the confined oil-CO2 MMP decreases with diminishing pore radius, a trend more pronounced in smaller pores. Beyond a pore radius of 10 nm, the confined MMP becomes less sensitive to radius changes. Additionally, for each pore radius, the confined oil-CO2 MMP initially increases then decreases with rising temperature, suggesting a maximum MMP at a specific temperature. There is also a maximum confined MMP for each pore radius at the given temperature, which decreases with smaller pore radius. Additionally, the calculated MMPs considering the presence of the second liquid phase is larger than that without this consideration.

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Primary author: CHEN, Zhuo (University of Alberta)

Co-authors: Dr LI, Ruixue (Chengdu University of Technology); Dr SHI, Jialin (East China University of Science and Technology)

Presenter: CHEN, Zhuo (University of Alberta)

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