Phase Behaviour Study of Bakken Crude Oil–CO_2 System: Solubility, Swelling/Extraction, and Miscibility Tests

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Abstract

Solid knowledge of the mutual interactions between CO_2 and reservoir crude oil is very critical for any CO_2-based enhanced oil recovery (EOR) process. CO_2 solubility in crude oil and the resulting oil swelling, light hydrocarbon extraction, interfacial tension (IFT), and minimum miscibility pressure (MMP) are among the most principal PVT properties affecting the recovery mechanisms contributing to the oil production. In this study, series of laboratory phase behaviour studies were carried out on a crude oil sample from Bakken formation to investigate the aforementioned crude oil– CO_2 mutual PVT properties.

CO_2 solubility measurement tests showed that at constant temperatures, an increase in CO_2 solubility value was observed for crude oil–CO_2 mixture when the equilibrium pressure increases. Furthermore, the solubility of CO_2 reduces with increased temperature. It was also found that at a constant temperature, the oil swelling factor (SF), increases up to a pressure so called extraction pressure(P_{ext}), at which majority of the light to medium hydrocarbon components in the oil phase are extracted by CO_2 and vaporized into the CO_2-rich phase. Additionally, it was observed that for the pressures higher than the extraction pressure, the oil-swelling factor reduced with equilibrium pressure because more hydrocarbon components were extracted at higher pressures. The extraction pressure was determined at different temperatures and results revealed that the extraction pressure increases by increasing temperature. In addition, the MMP of crude oil–CO_2 system was determined by analyzing the oil swelling factor curve corresponding the equilibrium pressures beyond the extraction pressure. It was seen that the reduction behavior of oil swelling factor after the extraction pressure occurs in two distinct regions. The oil-swelling factor decreased sharply right after extraction pressure denoted in this study as upper extraction phase (UEP), and then declined gradually which is called as lower extraction phase (LEP). Finally, the MMP of the crude oil– CO_2 system at a specific temperature was estimated by finding the intersection of the linear regression correlation corresponding each of the aforementioned regions (i.e., UEP and LEP). The crude oil–CO_2 MMP was also determined by employing vanishing interfacial tension (VIT) technique and series of CO_2 injection tests. Comparing the MMPs of the crude oil–CO_2 system determined by three methods revealed that the MMP values estimated by swelling/extraction data are in an appropriate agreement with those determined by the two later methods.