Phase Behaviour Study of Bakken Crude oil–CO$_2$ System: Solubility, Swelling/Extraction, and Miscibility Tests

Farshid Torabi, Ali Abedini, Nader Mosavat

Petroleum Systems Engineering, Faculty of Engineering and Applied Science, University of Regina, Regina, SK, S4S 0A2, Canada

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.