In-situ observation of water, oil and coal under high CO_2 pressure for CO_2-EOR and ECBMR

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In geologic CO_2 sequestration, the pH of formation water may be reduced due to CO_2 dissolution, which may cause the change of porosity and permeability of reservoir rock. The pH changes of formation water are widely varied depending on CO_2 pressure and the content of substances having pH buffering action, therefore, it is important to determine the wide range of pH change of various types of formation water under the various CO_2 pressure conditions. We considered a determination method of pH change of various types of formation water under the various CO_2 pressure conditions based on the spectrophotometry using a windowed high-pressure cell and a mixed pH indicator consisting of 4 single pH indicators. The well-defined absorption peaks were found at the wavelength of 614 nm or 444 nm when the pH of the solution was ≥5.6 or <5.6 respectively, therefore, two different calibration curves were derived from the absorbance of standard pH buffer solutions at each wavelength. The validity of this method was confirmed by an experimental result that the pH change of deionized water under 0.1 MPa CO_2 pressure had been determined accurately by this method. We carried out experiments on this method using the real formation water samples which contained bicarbonate ion having pH buffering action with different concentration under various CO_2 pressure. The results of the experiments demonstrated that this method is capable of determining the pH change of various types of formation water under various CO_2 pressure conditions.
Oil swelling is an important phenomenon in CO_2-EOR. According to various studies in the past, the degree of oil swelling depends on the partial pressure of CO_2, temperature, and oil composition. However, we expect that other factors, such as oil saturation, capillary pressure, and grain size of reservoir rock must be also considered in evaluating oil swelling because they may influence the interfacial area between oil and CO_2, which affects the dissolubility of CO_2 in oil. Therefore, we had made clear the effect of the interfacial area on oil swelling in this study. Oil and CO_2 were injected into a small see-through windowed high-pressure cell and oil swelling was observed under a microscope. The swelling factor increased with the increase of the specific interfacial area between oil and CO_2. Moreover, oil swelling in porous media was observed by using micro-models which had been made of 2 different diameter glass beads. Swelling factor in fine beads micro-model became larger than that in coarse beads micro-model whose interfacial area between oil and CO_2 was smaller than that of fine beads micro-model. Therefore, the swelling factor is expected to be larger with an increase in the interfacial area in porous media. These results suggest that the oil swelling should be expressed as a function of oil saturation, capillary pressure, and grain size of reservoir rock which are related to the interfacial area as well as the partial pressure of CO_2, temperature, and oil composition.
Coal swelling is also an important phenomenon in CO_2-ECBMR. The reduction of permeability of coal seam will be caused by the swelling phenomenon. The coal swelling should be controlled by a certain method in order to prevent the permeability reduction. Coal and CO_2 were injected into a small see-through windowed high-pressure cell and coal swelling was observed under a microscope. The coal swelling became smaller as the temperature was higher. This result suggest that the coal swelling can be controlled by heating the coal seam around the injection well.

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