An accurate mutual solubility model of multicomponent gas and brine system for CO$_2$ injection in saline aquifers with impurities

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Abstract

In CO$_2$ saline aquifer storage or CO$_2$ geological utilization (such as CO$_2$-EOR and CO$_2$-EWR) projects, reservoir simulation usually plays an important role for decision makings due to the complexity of underground environments. An accurate reservoir simulation model is always a key requirement of reservoir engineers and related stakeholders for real projects. In saline aquifers and depleted oil reservoirs, CH$_4$, H$_2$S or other gas components can be contained in an aquifer in terms of free gas or dissolved gas components. On the other hand, CO$_2$ co-injection with some impurities such as, O$_2$, N$_2$, SO$_x$ (oxysulphide), and/or NO$_x$ (oxynitride) can also be an option of CO$_2$ storage projects due to the high cost of CO$_2$ capture. When CO$_2$ is injected into saline aquifers with other gas components, the migration behavior is an interesting topic because gas-water properties (mutual solubility, density and viscosity) are different for different amount of impurities. The existence of fractures in reservoirs also influences the behavior of fluid migration. In our recent work, we have developed a new reservoir simulator with the following main properties: (1) Fully-implicit finite volume method with control-volume distributed multi-point flux approximation (CVD-MPFA); (2) Discrete-fracture model is employed where fractures are modelled with known exact geometrical information and location; (3) Compositional model for properties (mutual solubility, density and viscosity) of gas-water-oil phases is used.

In our previous work, we developed an accurate mutual solubility model for CO$_2$-CH$_4$-H$_2$S-brine system with fugacity-activity method which can be applied in wide range of temperature, pressure and salinity, and computational efficiency has been improved compared with traditional fugacity-fugacity model$^{[1]}$. In this work, the model is extended to CO$_2$-CH$_4$-H$_2$S-N$_2$-O$_2$-brine systems, with a comprehensive reviewing and regression of the current existing experimental data. The model is validated with N$_2$-brine system for a range of pressure from 1 to more than 1000 bar, a range of temperature from 0 to 250 $^\circ$C, and salt molality ranging from 0 to more than 6 mole/Kg water. For O$_2$-brine subsystem, the model is validated for a range of pressure from 1 to 200 bar, temperature range of 0 to more than 300 $^\circ$C and salt molality range of 0 to 6 mole/Kg water. Most of the experimental data points can be predicted by the model with 10% relative difference. The existing experimental work of subsystems CO$_2$-N$_2$-brine, CO$_2$-O$_2$-brine, CO$_2$-CH$_4$-N$_2$-brine, CO$_2$-H$_2$S-N$_2$-brine and N$_2$-O$_2$-brine are compared with the model predictions which show good behavior of the new model.
The new model is successfully implemented in our reservoir simulator. Several examples are presented in the paper: (1) CO₂ co-injection with N₂ and/or O₂ into saline aquifer where the model is based on a demonstration project of CO₂ saline aquifer storage in Tongliao, inner Mongolia, China, and the results obtained by this simulator are compared with the results produced by TOUGH2 with an EOS module, EOS7Cm[2]; (2) CO₂ co-injection with N₂ and/or O₂ into a saline aquifer with fractures, and the gas migration behaviors are compared with the results from the model without fractures; the influences from different types of fractures are analyzed with the simulation results; (3) CO₂ co-injection with N₂ and/or O₂ into a CH₄ saturated aquifer, and the influences of CH₄ existence in a reservoir are evaluated with the simulation results.

References