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A Correlation of the Interfacial Tension between Supercritical Phase CO₂ and Equilibrium Brines as a Function of Salinity, Temperature and Pressure

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Abstract

The modeling of CO₂ sequestration in saline aquifers is becoming increasingly important as this method emerges as the prime technology available for the disposal of large volumes of anthropogenically-generated CO₂, thus reducing atmospheric CO₂ emissions. The interfacial tension between the saline brine in the aquifer and the injected CO₂ phase has a strong effect on the capillary pressure and relative permeability characteristics of the CO₂-brine displacement, and proper understanding of the IFT level is necessary for accurate modeling and evaluation of such a process. This paper provides a summary of 168 brine-CO₂ interfacial tension measurements conducted using a drop pendant interfacial tension apparatus at temperatures ranging from 41 to 125°C, pressures from 2,000 to 27,000 kPag and salinities from 0 ppm (distilled water) to over 334,000 ppm. The dataset was regressed to develop an empirical correlation to predict the brine-CO₂ IFT over the range of conditions evaluated in this work. The correlation, including temperature, pressure and salinity dependence, fits the measured data with an overall regression coefficient in excess of 0.94. In addition, a very strong relationship was found between computed gas-water ratio (dissolved CO₂) and interfacial tension. An additional correlation was developed to model this effect, also with a high regression coefficient of 0.92. Since the gas-water ratio is a much easier parameter to measure than IFT, this provides a rapid and inexpensive method to estimate in-situ IFT from available or CO₂ solubility data.

Introduction

Interpretation of the historical temperature record on a scale of centuries to millennia indicates a slight increase in global average annual temperatures in the last 150 years, in the order of 0.76°C, and predictions are that if this trend continues unabated, humankind is facing significant climate change by the end of this century, resulting in an average increase in global temperature in the 1.1-6.3°C range depending on the greenhouse gas emission scenario considered.¹ It is generally accepted that the main cause of the observed global warming is the increase in atmospheric concentrations of greenhouse gases, such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O).¹ Of all the greenhouse gases, CO₂, whose atmospheric concentrations have risen from pre-industrial levels of 280 ppm to 380 ppm in 2005, is the most important greenhouse gas, believed to be responsible for approximately two thirds of the enhanced 'greenhouse effect'.^{1,2} A major challenge in mitigating climate change effects is the reduction of CO₂ emissions to the atmosphere, which hopefully will lead to a stabilization of CO₂ concentration to no more than double the pre-industrial level at around 550 ppm (i.e., double the pre-industrial level), for which a corresponding average global warming of between 2 and 4.5°C is likely.¹ In the broad portfolio of measures and actions that are envisaged for reducing anthropogenic CO₂ emissions into the atmosphere, CO₂ Capture and Storage (CCS), which entails CO₂ capture from large industrial processes, mainly power generation based on fossil fuels, and injection into deep geological formations, plays an important role.^{3,4}

Carbon dioxide can be sequestered in geological media through a variety of mechanisms: static or hydrodynamic trapping below caprock in oil and gas reservoirs and deep saline aquifers; dissolution in reservoir oil or formation water; in-situ mineral carbonation; and/or adsorption onto organic matter in coal and shale.⁵ More recently, CO₂ retention as an immobile phase trapped in the pore space of deep saline aquifers has also been identified as an important CO₂ storage mechanism.⁶ Deep saline aquifers offer the advantage that they are ubiquitous in sedimentary basins, have the largest