



## CHAPTER I INTRODUCTION

During secondary oil recovery, fluid is injected into the reservoir to maintain the pressure to force the remaining oil to the production well. The fluid normally injected to displace the oil is seawater, which contains sulfate anions ( $\text{SO}_4^{2-}$ ). The water present in the reservoir, called the formation water, usually contains significant amounts of salts of divalent cations such as calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ), barium ( $\text{Ba}^{2+}$ ), and strontium ( $\text{Sr}^{2+}$ ) ions. These ions can react with  $\text{SO}_4^{2-}$  to form scale when the formation water is mixed with the incompatible seawater resulting in scale precipitation and deposition, especially of barium sulfate ( $\text{BaSO}_4$ ). Barium sulfate scale can occur anywhere in the production system, such as around wellbore surface, in porous formation, and on the surface of production equipment (Allen and Roberts, 1989 and He *et al.*, 1996). If the scaling problem is unsuitably treated, continuous scale growth can eventually lead to the blockage of the oil flow path, damage the production system, and consequently decrease in the system efficiency and productivity. When the production decreases to an unacceptable level due to scale blockage, the production system is shut down to remove the scale. This shutdown can cost the oil producers millions of dollars per year in productivity loss and overhaul expense (Dunn *et al.*, 1999).

Barium sulfate scale is a very insoluble salt and extremely difficult to be chemically removed. Thus, methods for preventing scale formation are in order, and one such method is the precipitation squeeze treatment technique. In this technique, the scale inhibitor is injected into the reservoirs during production downtime, the shut-in period, and retained in the formation either by adsorption onto the porous media surface or by formation of soluble salt precipitate with divalent cations, especially calcium. After the shut-in period, normal production is resumed and the scale inhibitor contained in precipitate is gradually released back into the produced fluid at proper concentration to inhibit or slow the scale nucleation and growth (Browning and Fogler, 1993).

As mentioned above, when two incompatible fluids are mixed and the  $\text{Ba}^{2+}$  cation and  $\text{SO}_4^{2-}$  anion are present in concentrations exceeding the solubility product

( $K_{sp}$ ) of barium sulfate, i.e.  $1.08 \times 10^{-10} \text{ M}^2$ , barium sulfate precipitate can form until the solubility product is no longer exceeded (Dunn *et al.*, 1999). Even if the solubility product is exceeded, it can take as long as a year to reach the onset of barium sulfate precipitation and start forming nuclei, especially when the ionic activity product is only slightly greater than the solubility product (Blaedel and Meloche, 1957). The term of supersaturation ratio, which is the ratio of the ionic activity products (i.e., barium and sulfate) to the solubility product, is normally used to represent the degree of saturation in the precipitation system (He *et al.*, 1996).

In this study, the formation of barium sulfate precipitates was studied. The critical supersaturation ratio is defined as the ratio at which the barium sulfate precipitate can be observed at any particular testing time. This ratio was obtained from different precipitation conditions and used as an index to evaluate the effectiveness of different types of scale inhibitors. The effects of testing time, scale inhibitor concentration, and solution pH on the barium sulfate formation were also investigated. Finally, the morphology, the elemental analysis, and the particle size distribution analysis of the resulting  $\text{BaSO}_4$  precipitates were comparatively studied.