Kinetic modeling of pH and temperature effects on silica polymerization

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Silica scale formation is one of the significant problems for the practical operation of geothermal plants because geothermal fluids used for the electricity generation often contain a high amount of silicic acid. Acidification of geothermal fluid (pH<6) is a general process to avoid silica scale formation; however, this could cause corrosion of metal pipes. In this study, we investigated the effect of pH and temperature (298–353 K) on the polymerization rate of silica and examined optimal pH and temperature conditions on the treatment process of waste geothermal fluids. When silica solution (500 mg/dm^3) reacted at different pH 3, 6, and 9 for 336 h, initial decrease patterns of dissolved silica concentrations (<0.1um) were different in pH condition at 298 K; it reduced to 200 and 400 mg/dm^3 at pH 6 and 9 within 48 h, respectively, whereas did not change at pH 3. This initial decrease of dissolved silica concentration is related to the nucleus growth in the early stage of silica polymerization, followed by the aggregation as the latter stage of the polymerization. At pH 6, since nucleus growth was most promoted at 298 K, the pseudo-equilibrium concentration of dissolved silica concentration gradually increased with increasing temperature and was 400 mg/dm^3 at 333 K. However, its rates were almost same at the pH. Furthermore, the induction periods until start to nucleus growth were prolonged with increasing temperature and its reaction did not start at 353 K. The pseudo-equilibrium concentration was represented the Van't Hoff equation. On the other hand, at pH 9, the pseudo-equilibrium concentration reduced from 400 mg/dm^3 at 298 K to 300 mg/dm^3 at 313 K, while no polymerization was found over 333 K. The rate constants in nucleus growth reaction period were three times higher at pH 9 than that at pH 6 whereas it for aggregation reaction was a thousand-fold lower at pH 9 than that at pH 6. The differences of those values became small over 313 K. Our results, therefore, suggest neutral pH conditions are the most suitable to suppress the silica scale, and then the optimal temperature for the treatment could be estimated from the initial silica concentration according to this kinetic model.