# CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

The dissolution and the precipitation experiments show some promising results for the industry as well as the academia. Irrespective of the type of acid, the analcime dissolution follows the Langmuir-Hinschelwood rate law analogous to the Michaelis-Menten equation for enzymatic reactions. The dissolution in different acid have been found to remain same at the same [H+] concentration, indicating that the dissolution is independent of the acid anions and that the rate appears to be depending only on the [H+] concentration. In field conditions the amount of time required for the dissolution of the same amount of acid would be the same. Some other organic acids such as citric acid shall be studied to see whether the rate is same with the mineral acids. Some preliminary results have shown that at very low pH conditions, the rate of dissolution may be high in citric acid. However, this needs to be substantiated by further experiments before it is concluded that the anions of the acid have any effect on the dissolution.

The dissolution of analcime under the base case conditions appears to be Aluminum facilitated as suggested by Hartman and Fogler (2006). Also, the Si/Al ratio of the partially dissolved particles indicates that there is some amount of Al that is left in the framework which doesn't dissolve in the later stages of the reaction. It would however be important to look whether the dissolution follows the Al removal model suggested my Hartman and Fogler (2006). In that model, the rate of Al removal has been related to the amount of Al sites that are present at any time during the reaction as shown in the following equation,

$$\ln(\theta) = \ln(\frac{S_T}{S_o}) = -k_3 f[H^+]t$$

Here, S_T is the total number of Al sites remaining at any time and S0 is the initial number of sites. A site is defined as the Al-----O bond where the attck by [H+] takes place. The right hand side of t he equation shows a function of [H+] that is the rate law dependence of the H+ concentration given by the Michaelis-Menten equation.

Experiments can be conducted and the Al concentration be found at different times to give the total number of sites. If the model is being obeyed by all the other acids, a straight line should result from the plot of ln(θ) vs time.
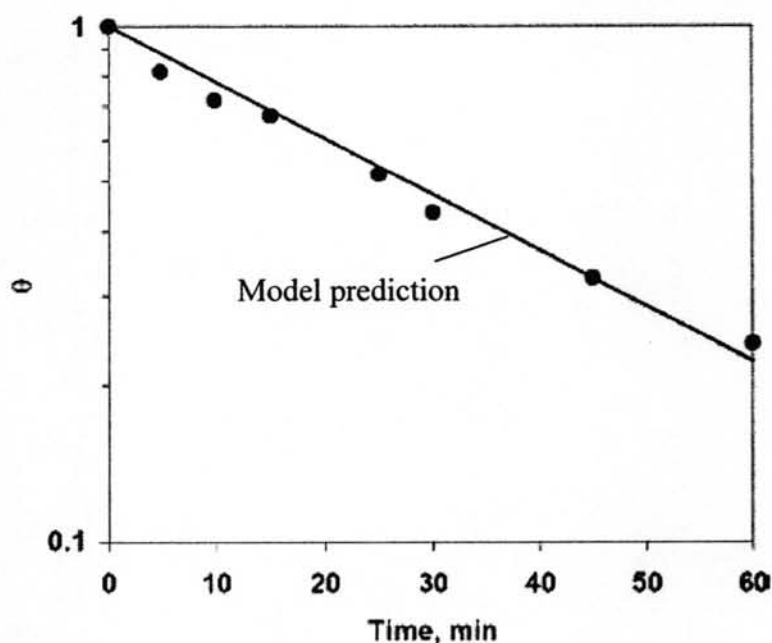
Fig 5.1 Al facilitated dissolution model for analcime in HCl (From Hartman and Fogler, 2006)

Another area of significant importance is to explore the reasons behind the different plateau heights in the different acids. It has been observed that the acids showing higher plateau height also show a longer precipitation lag time, indicating that the same property of the anion may be responsible for both the phenomena. One of the hypotheses proposed for the different plateaus heights is that precipitation may be taking place even during the reactions. There may also be condensation of silanol bonds (Si----O----Si) taking place during the dissolution. The anions of the acids may be affecting these phenomena differently. In other words, the anions facilitating the condensation or the precipitation more will show a smaller plateau height and a smaller precipitation lag time, as we saw in the case of sulfuric acid. As a first guess an experiment of analcime dissolution in HCl in the presence of sulfate ions could be done. The expected results would be as shown in the figure below.

Si conc

Analcime dissolution in HCl without sodium sulfate

Analcime dissolution in HCl
with sodium sulfate

time
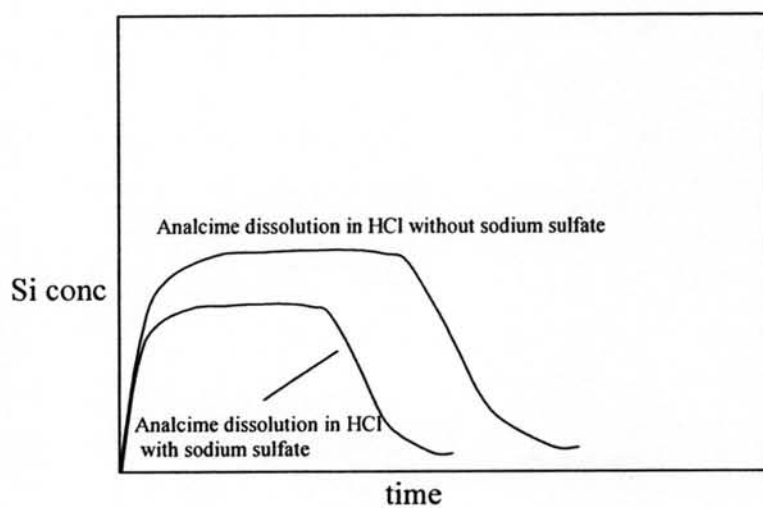
Fig 5.2 Comparison of analcime dissolution in HCl with and without sodium sulfate

Another way to check the hypothesis would be to do FT-IR studies on the re-acting particles during dissolution for the formation of Si---O----Si bonds if conden-sation is going on during the dissolution.