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APPENDIX

1. Determination of Analcime Chemical Composition Using Atomic Absorption Spectroscopy

The molar ratio of Si/Al/Na was determined from atomic absorption spectroscopy. A sample of analcime 0.3004 g was dissolved in 100 ml of 3.84% hydrofluoric acid.

Analcime $Na_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$

Mass (g)	Si (ppm)	Al (ppm)	Na (ppm)
0.3004	1600.35	736.209	611

Observed moles ratio of Al: Si: Na   = 1: 2.09: 0.985

Theoretical moles ratio of Al: Si: Na = 1: 2: 1

2. Kinetic Analysis of Analcime Dissolution for Batch Experiments

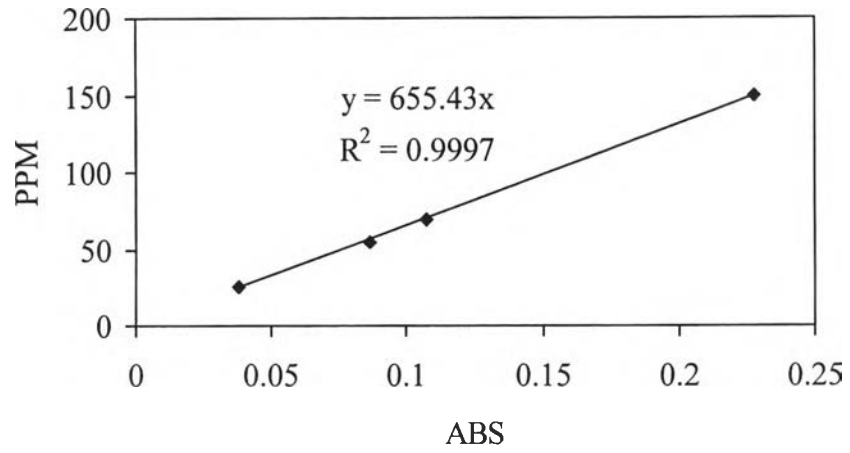Experimental Conditions:

Weight of analcime   = 2 g

HCl concentration   = 2 M
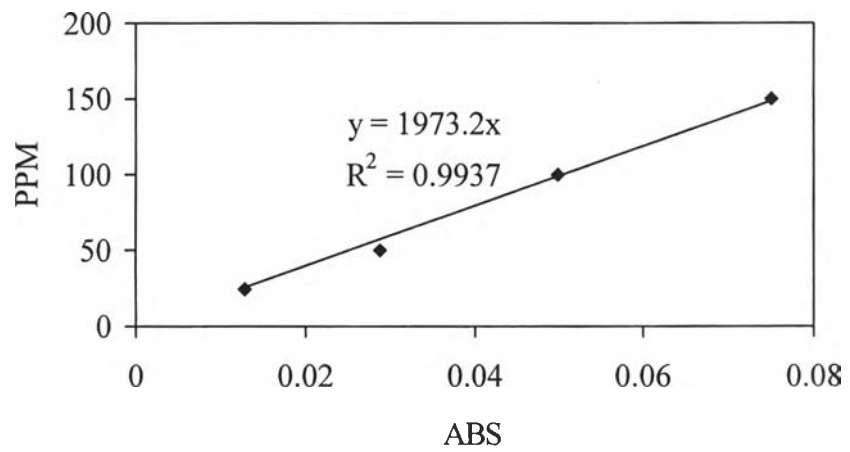
Volume of HCl used = 300 ml

Temperature   = 25°C

Stirring rate   = 1100 rpm

Calibration Curve of Aluminum

$y = 655.43x$

$R^2 = 0.9997$

Calibration Curve of Silicon

$y = 1973.2x$

$R^2 = 0.9937$

For Aluminum

Time (min)	ABS	Conc. of Al (mg/l)	Volume of solvent in each vial (l)	Al in each vial (mg)	Acc. Al in vial (mg)	Solvent (l)	Tot. Al dissolved (mg)	Tot. Al disolved/g analcime (mmolAl/g)
0	0	0	0	0	0	0.300	0	0
1	0.011	7.20973	0.005	0.03604865	0.03604865	0.295	2.1629190	0.040054056
3	0.042	27.52806	0.005	0.13764030	0.17368895	0.290	8.15682635	0.15105234
5	0.073	47.84639	0.005	0.23923195	0.4129209	0.285	14.04914205	0.260169297
7	0.107	70.13101	0.005	0.35065505	0.76357595	0.280	20.40025875	0.377782569
10	0.161	105.52423	0.005	0.52762115	1.29119710	0.275	30.31036035	0.561302969

For Silicon

Time (min)	ABS	Conc. of Si (mg/l)	Volume of solvent in each vial (l)	Si in each vial (mg)	Acc. Si in vial (mg)	Solvent (l)	Tot. Si dissolved (mg)	Tot. Si dissolved/g analcime (mmolAl/g)
0	0	0	0	0	0	0.300	0	0
1	0.009	17.7588	0.005	0.088794	0.088794	0.295	5.32764	0.094831613
3	0.027	53.2764	0.005	0.266382	0.355176	0.29	15.805332	0.281333784
5	0.048	94.7136	0.005	0.473568	0.828744	0.285	27.82212	0.495231755

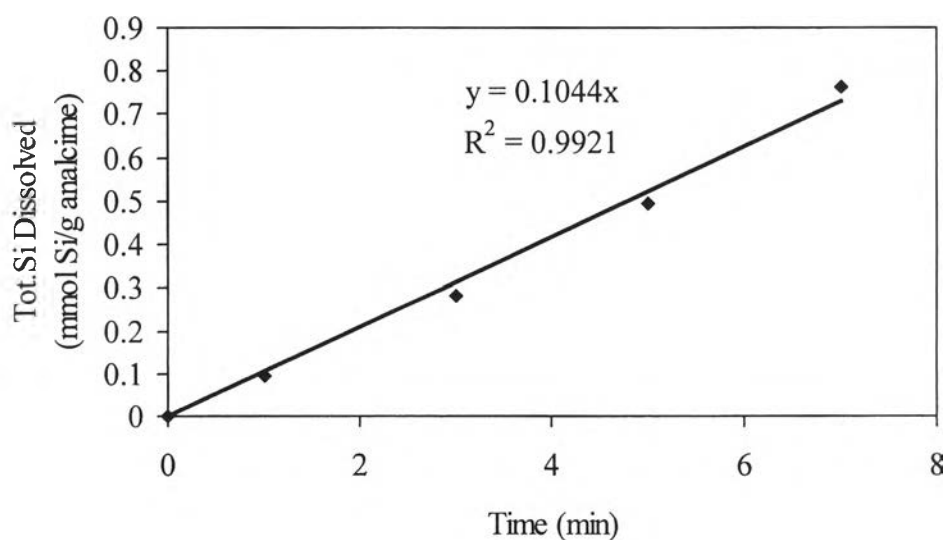Calculation of Initial Dissolution Rate of Aluminum

Plot graph between total aluminum dissolved in HCl solution and time
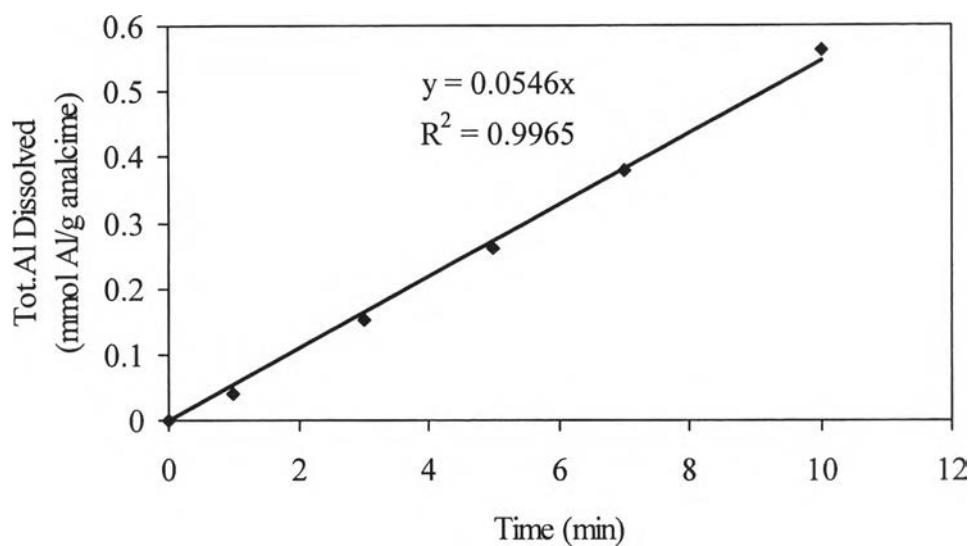
$\therefore$ Initial dissolution rate of aluminum = 0.0546 mmol Al/g·min

Calculation of Initial Dissolution Rate of Silicon

Plot graph between total silicon dissolved in HCl solution and time

$\therefore$ Initial dissolution rate of silicon = 0.1044 mmol Si/g·min

3. Calculation of Activation Energy (E)

The specific rate constants for the dissolution of aluminum from analcime in HCl at 25°C and 45°C were found to be 2.54×10^{-5} and 1.306×10^{-4} mole analcime/(g·min·HCl molarity), respectively.

A quantitative relationship for the activation energy is given by the Arrehenius equation.

$$k = A \exp(-\frac{E}{RT}) \quad (3)$$

Where k = specific rate constant

A = frequency factor or pre-exponential factor (a constant)

E = activation energy (Cal/mol)

R = gas constant = 1.987 Cal/mol/K

T = absolute temperature (K)

From equation (3);

$$\frac{k_2}{k_1} = \exp((-\frac{E}{R})(\frac{1}{T_1} - \frac{1}{T_2})) \quad (4)$$

$$\ln\frac{k_2}{k_1} = (-\frac{E}{R})(\frac{1}{T_1} - \frac{1}{T_2}) \quad (5)$$

On rearrangement equation (5) gives

$$E = R \ln(\frac{k_2}{k_1})(\frac{T_1 T_2}{T_2 - T_1}) \quad (6)$$

The activation energy, E for dissolution of aluminum from analcime in hydrochloric acid was calculated by equation (6).

$$E = 1.987 \times \ln(1.306 \times 10^{-4}/2.540 \times 10^{-5}) \times (\frac{298.16 \times 318.16}{318.16 - 298.16}) \quad \text{Cal/mol}$$

$$= 15431.74 \text{ Cal/mol}$$

$$= 15.43 \text{ kCal/mol}$$

4. Kinetic Analysis of Analcime Dissolution for Differential Experiments

Weight of analcime (W)   = 0.2 g

HCl concentration   = 1 M

Flow rate of HCl used (v_0) = 15 ml/min

Temperature   = 25°C

Calibration Curve of Aluminum
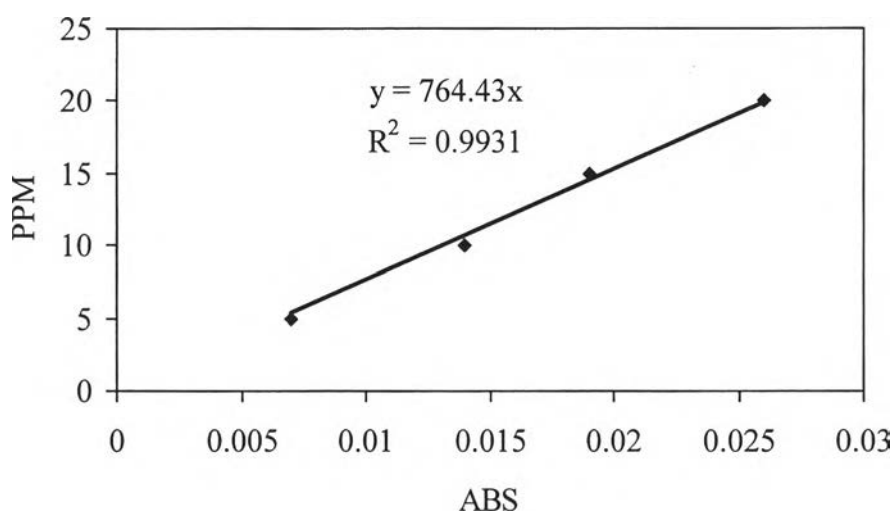
The dissolution rate of aluminum and silicon were calculated by this equation:

$$-r = \frac{C_p v_0}{W} \tag{7}$$

where   −r = rate of dissolution of analcime, mol Al/g of analcime·min

C_p = production concentration, mol/l

v_0 = volumetric flow rate of HCl solution, l/min

W = weight of analcime, g

For Aluminum

Time (min)	ABS	PPM (mg/l)	Conc. of Al (M)	$-r_{Al}$ (mol Al/g·min)
0	0	0	0.00000	0
0.333	0.018	13.75974	0.00051	3.82215×10^{-5}
0.667	0.018	13.75974	0.00051	3.82215×10^{-5}
1.000	0.018	13.75974	0.00051	3.82215×10^{-5}
1.333	0.018	13.75974	0.00051	3.82215×10^{-5}
1.667	0.018	13.75974	0.00051	3.82215×10^{-5}

∴ Initial dissolution rate of aluminum = 3.82215×10^{-5} mol Al/g·min

5. Characterization of Analcime Particles After Dissolved by 7 M HCl for 9 Minutes.
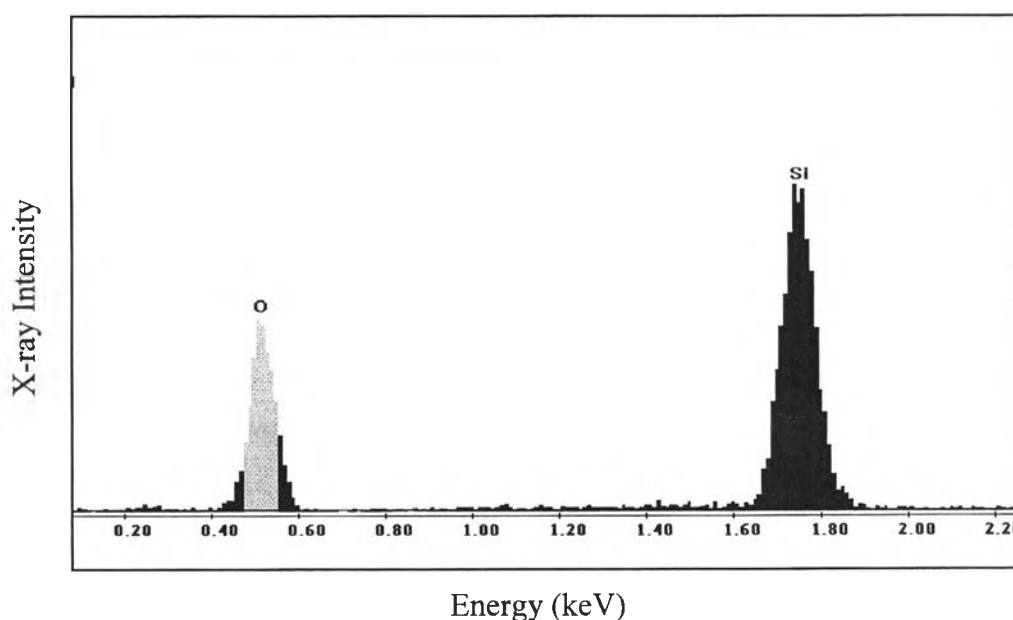

Figure 1 EDX Analysis of Analcime Particles After Dissolved by 7 M HCl for 9 Minutes.
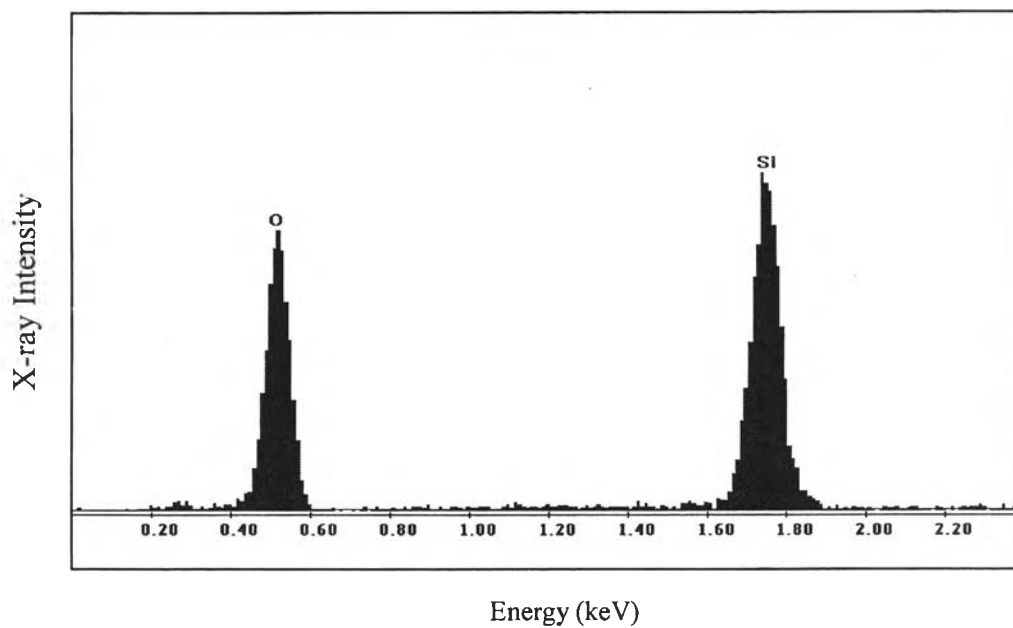
6. Confirmation of Silica Gel Formation

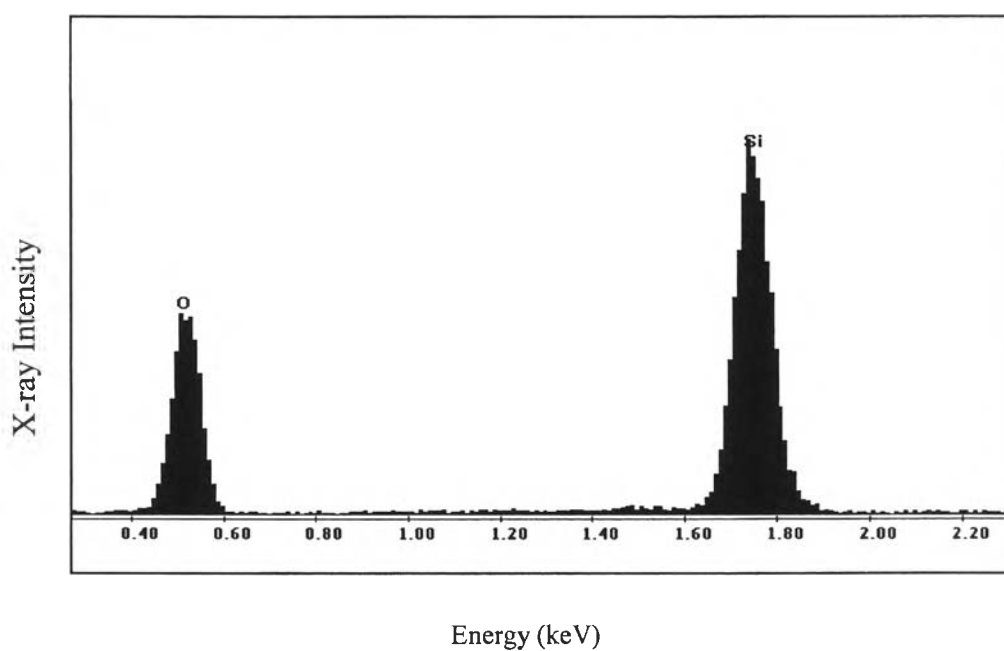Figure 2 EDX analysis of silica gel precipitates from the experiment using 4 M HCl at 25°C.

Figure 3 EDX analysis of silica gel precipitates from the experiment using 7 M HCl at 25°C.

CURRICULUM VITAE

Name: Ms. Phan-on Wattanaparadorn

Date of Birth: December 3, 1979

Nationality: Thai

University Education:

1996-2000   Bachelor Degree of Engineering (2nd Class Honours) in Chemical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand