

**INHIBITION OF SILICATE PRECIPITATION  
DURING ANALCIME DISSOLUTION**

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**ABSTRACT**

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Acidization is a common technique for increasing well productivity by injecting acid into the formation at low pressure to achieve radial penetration into formation. However, the presence of zeolite could result in silicate precipitation and hence decrease the productivity. This study investigates the dissolution of analcime in HCl and in citric acid and subsequent silicate precipitation. The results showed that the dissolution of analcime in HCl was through aluminum selective removal from the framework and followed Michaelis-Menten model. The activation energy of the reaction was also calculated. Increasing the amount of analcime, citric acid concentration or temperature resulted in an increase of silicate precipitation rate. Citric acid was found to increase analcime dissolution rate compared to HCl at the same initial pH. The induction time of silicate precipitation in citric acid was found to be longer than in HCl at the same pH. A hypothesis for these phenomena also presented.

## บทคัดย่อ

พรชัย แซ่ถิ่ม : การชะลอการตกตะกอนของซิลิเกตระหว่างการละลายของอะนัลซิม (Inhibition of Silicate Precipitation during Analcime dissolution) อ. ที่ปรึกษา : ผศ. ดร. ปมทอง มาลากุล ณ อุรุยา, ศ. เอช สกอตต์ ฟอกเลอร์ (Prof. H. Scott Fogler) เอกสารจำนวน 60 หน้า ISBN 974-9937-69-4

การบำบัดด้วยกรดเป็นวิธีการหนึ่งในการเพิ่มผลผลิตของกลุ่มน้ำมัน โดยการฉีดกรดลงไปในกลุ่มผลิตด้วยความดันต่ำเพื่อเพิ่มการซึมซาบของน้ำมันในแนวรัศมี อย่างไรก็ตามในระหว่างการบำบัด หากมีซิลิโกล์อยู่ในกลุ่มผลิตจะก่อให้เกิดการตกตะกอนของซิลิเกต ซึ่งจะลดความสามารถในการผลิตลง งานวิจัยนี้ศึกษาการละลายของอะนัลซิมในกรดไฮโดรคลอริกและกรดซัลฟูริกและการตกตะกอนของซิลิเกตภายหลังการละลายของอะนัลซิม การละลายของอะนัลซิมเป็นผลมาจากปฏิกิริยาที่เฉพาะเจาะจงของการละลายอลูมิเนียม ออกจากโครงสร้างผลึกของอะนัลซิม และเป็นไปตามโมเดลของ Michaelis-Menten ค่าพลังงานกระตุ้นของปฏิกิริยาการละลายของอะนัลซิมในกรดไฮโดรคลอริกได้ถูกคำนวณไว้ หากเปรียบเทียบอัตราเร็วของปฏิกิริยาการละลายของอะนัลซิมในกรดไฮโดรคลอริก และกรดซัลฟูริกที่ความเข้มข้นเริ่มต้นของไฮโดรเจนไอออนเท่ากันพบว่า อัตราการละลายในกรดซัลฟูริกสูงกว่าในกรดไฮโดรคลอริก จากการศึกษาการตกตะกอนของซิลิเกตในกรดซัลฟูริกพบว่า อัตราเร็วของปฏิกิริยาการตกตะกอนจะเพิ่มขึ้นเมื่อเพิ่มอุณหภูมิ, ปริมาณของอะนัลซิม หรือความเข้มข้นของกรด เมื่อเปรียบเทียบระหว่างกรดซัลฟูริกและกรดไฮโดรคลอริกพบว่า กรดซัลฟูริกใช้เวลาเหนี่ยวนำในการตกตะกอนของซิลิเกตนานกว่าที่ความเป็นกรด-ด่างเดียวกัน สมมติฐานของปรากฏการณ์ ต่าง ๆ ที่ได้กล่าวมาได้ถูกแสดงไว้ในงานวิจัยนี้

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**ABBREVIATIONS**

EDTA	Ethylene Diamine Tetra Acetic acid
EDX	Energy Dispersive X-ray Analysis
HCl	Hydrochloric acid
HF	Hydrofluoric acid
ICP	Inductive Couple plasma
KCl	Potassium Chloride
RLS	Rate Limiting Step
SEM	Secondary Electron Microscope
XRD	X-ray Diffraction

## LIST OF SYMBOLS

A	frequency factor or pre-exponential factor
CA	molecular citric acid
$C_{H^+ \cdot S}$	the concentration of the sites occupied by adsorbed hydrogen ion
$C_T$	the total concentration of sites that can be occupied
$C_{wp}$	The Weisz-Prater Criterion
D	diffusivity
$D_{AC}$	degree of acid catalysis
$D_p$	particle diameter
$E_a$	activation energy
$\Delta G$	active free energy
$\Delta G^*$	critical active free energy
$H^+$	bulk concentration of hydrogen ion
J	nucleation rate for homogeneous nucleation
$K_0$	kinetic coefficient
$K_A$	equilibrium adsorption constant for hydrogen ion
$K_a$	equilibrium dissociation constant
$K_B$	equilibrium adsorption constant for citric acid
$K_m$	Michaelis-Menten constant
k	specific reaction rate constant
$k_b$	Boltzmann constant
$k_c$	mass transfer coefficient
$N_{H^+}$	molar flux of hydrogen ion
R	gas constant
Re	The Reynolds number
-r	overall rate of dissolution
$-r_0$	un-catalyzed reference rate

## LIST OF SYMBOLS

$r^*$	initial dissolution rate
$Sc$	The Schmidt number
$Sh$	The Sherwood number
$S_T$	total site
$V_{max}$	maximum rate of dissolution
$\rho_c$	particle density
$\beta$	supersaturation ratio
$\Omega$	volume of a molecule inside the crystal
$\gamma$	interfacial free energy between nucleus and solution
$\alpha$	fraction of ionic species
$\eta$	effectiveness factor
$\phi$	Thiele modulus