

## Elovich

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### چکیده

( Aqua Regia)

Elovich

( Elovich Power SCM HDM)

Elovich

واژه های کلیدی:

مقدمه

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( PGM)

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جدول ۱: تعداد مقالات و ثبت روش‌های بازیابی پلاتین از کاتالیزورها [2].

Period	1993 to 2003	1975 to 1992
Patent	43	38
Reviews	11	2
Articles	34	7

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( $\gamma$ -Al<sub>2</sub>O<sub>3</sub>)

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3HCl:1HNO<sub>3</sub>

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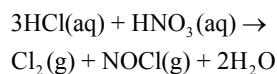
(Jafarifar, 2005) (Barakat, 2004)

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NOCl Cl<sub>2</sub>

روش های استخراج:

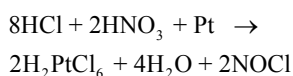


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Matjie et al.

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[ ] Acacia et al.

HNO<sub>3</sub> HCl NaF HF

H<sub>2</sub>O<sub>2</sub>

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[H<sup>+</sup>]

NaHSO<sub>4</sub> H<sub>2</sub>SO<sub>4</sub>

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(Aqua Regia)

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### نتایج آزمایشگاهی

Barakat &

[ ] Mahmud

جدول ۲: نتایج حاصل از آزمایش‌های استخراج بر گرد حاصل از فرآیند تولید اسید نیتریک [9].

time (min)	Recovery eff %	L/S	T °C
15	73.95	25	109
30	86.84	25	109
45	92.11	25	109
60	95.13	25	109
75	96.32	25	109
90	97.89	25	109
105	97.89	25	109
120	97.89	25	109
180	97.89	25	109
120	77.5	2.5	109
120	92.92	5	109
120	98.33	7.5	109
120	98.33	10	109
120	98.33	15	109
120	98.33	25	109
120	24.21	10	30
120	61.05	10	60
120	84.21	10	75.2
120	92.63	10	90
120	97.89	10	109

( )

[ ] Jafarifar & Daryanavard

جدول ۳: نتایج حاصل از آزمایش‌های استخراج بر کاتالیست مستعمل ریفورمینگ [10].

time (min)	Recovery eff %	L/S	T °C
20.45	75	10	109
40.15	85	10	109
61.19	91.9	10	109
80.6	95	10	109
100	95.95	10	109
119.7	96.67	10	109
140.15	96.67	10	109
157.2	96.67	10	109
180	68.4	1.49	109
180	84.02	2	109
180	94.02	3	109
180	96.96	4	109
180	96.96	5	109
180	96.96	6	109
180	96.96	7	109
180	96.96	8	109
180	96.96	9	109

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بررسی سینتیکی واکنش

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[ ] (HDM) - [ ] (SCM)

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:SCM

Power SCM HDM)

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R<sup>2</sup>

$$t \propto \frac{x}{x_{\infty}} \quad (1)$$

$$t \propto 1 - 3\left(1 - \frac{x}{x_{\infty}}\right)^{\frac{2}{3}} - 2\frac{x}{x_{\infty}} \quad (2)$$

$$t \propto 1 - \left(1 - \frac{x}{x_{\infty}}\right)^{\frac{1}{3}} \quad (3)$$

جدول ۴: نتایج حاصل از بررسی چهار مدل سینتیکی.

Model	Rate controlling Step	R <sup>2</sup> Linear correlation	
		Reforming catalyst	Nitric acid catalyst
SCM	a. Film diffusion	0.11	0.10
	b. Ash diffusion	0.75	0.75
	c. Chemical reaction	0.64	0.59
HDM	Film diffusion	0.97	0.88
Power	Reaction or mass transfer	0.91	0.96
Elovich	Reaction or mass transfer	0.99	0.97

:HDM

$$t \propto -\ln\left(1 - \frac{x}{x_{\infty}}\right) \quad (4)$$

[ ] (Power Law Model)

X<sub>∞</sub> X

:

$$\frac{dX}{dt} = k\left(1 - \frac{X}{X_{\infty}}\right)^n \quad (5)$$

$$n = 1 \Rightarrow kt = -X_{\infty} \ln(X_{\infty} - X) \quad (6)$$

$$n \neq 1 \Rightarrow kt = \frac{X_{\infty}^n}{(X_{\infty} - X)^{n-1}} \Rightarrow \quad (7)$$

$$\ln(t) = \ln\left(\frac{X_{\infty}^n}{k}\right) + (1-n)\ln(X_{\infty} - X)$$

جدول ۵: عوامل محاسبه شده در رابطه Elovich .

	Acid nitric catalyst	Reforming catalyst
α	6.911	7.013
a (1/min)	1.635	1.670
to (min)	0.088	0.085
R <sup>2</sup>	0.971	0.9856

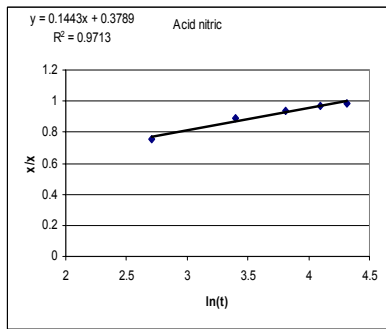
مدلسازی استخراج پلاتین با معادله Elovich

Elovich

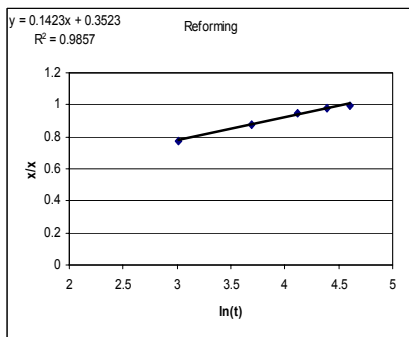
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$$er = \sum \left( \left( \frac{X}{X_{\infty}} \right)_{exp.} - \left( \frac{X}{X_{\infty}} \right)_{calc.} \right) / \left( \frac{X}{X_{\infty}} \right)_{exp.} \right)^2 \quad ( )$$



-a



-b

شکل ۱: نتیجه نهایی برازش داده‌های آزمایشی استخراج پلاتین از کاتالیست.

( ) Elovich  
 $X_{\infty}$  X

$$\frac{d \left( \frac{X}{X_{\infty}} \right)}{dt} = a e^{-\alpha \left( \frac{X}{X_{\infty}} \right)} \quad ( )$$

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 (  $X/X_{\infty} \rightarrow 0$  )

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 $t=0$   $X/X_{\infty}=0$   
 Elovich  
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$$\frac{X}{X_{\infty}} = \frac{1}{\alpha} \ln(1+t/t_0) \quad ( )$$

$$\Rightarrow \frac{X}{X_{\infty}} = \frac{1}{\alpha} \ln(t+t_0) - \frac{1}{\alpha} \ln(t_0)$$

$$t_0 = 1/\alpha a$$

$t_0$  ( )

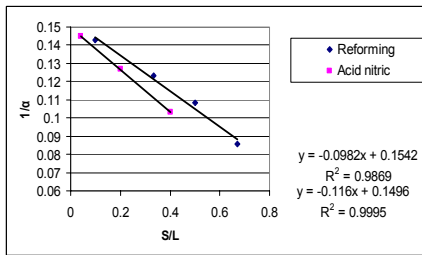
$t \gg t_0$   
 ( )

$$\frac{X}{X_{\infty}} = \frac{1}{\alpha} \ln(t/t_0) \quad ( )$$

a  $t_0$  ln(t)  $X/X_{\infty}$   
 1/α

ln(t+t<sub>0</sub>)  $X/X_{\infty}$   
 1/α a  $t_0$   
 $t_0$

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 1/α a )  
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شکل ۲: تابعیت خطی عامل  $1/\alpha$  بر حسب نسبت  $S/L$ .

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E Frequency factor A

$$a = A e^{-\frac{E_a}{RT}}$$

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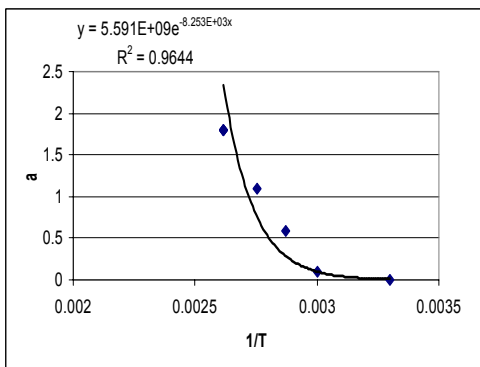
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( ) A

A = )

$$(5.591 \times 10^9)$$

$$68.62 \text{ kJ/mol}$$



شکل ۳: برازش داده‌های آزمایشی استخراج پلاتین از کاتالیست تولید اسید نیتریک در دماهای مختلف در معادله آرنیوس (۱۲).

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a 1/alpha

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1/alpha ( )

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1/alpha

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1/alpha

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a

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a

1/alpha

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1/alpha

( ) ( )

1/alpha

(( ) )

( S/L)

Reforming catalyst:

$$\frac{1}{\alpha} = 0.1542 - 0.0982 \left(\frac{S}{L}\right)$$

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Acid nitric catalyst:

$$\frac{1}{\alpha} = 0.1496 - 0.1160 \left(\frac{S}{L}\right)$$

( )

1/alpha

H<sup>+</sup>

[H<sup>+</sup>]

جدول ۶: نتایج حاصل از بهینه‌سازی عوامل معادله Elovich برای حالت‌های مختلف با MATLAB.

Description	err	Acid nitric Cat.		Reforming Cat.	
		1/α	a (1/min)	1/α	a (1/min)
Without optimization	0.0049	0.145	1.635	0.143	1.670
Optimize 1/α	0.0051	0.146	1.635	0.146	1.670
Optimize a	0.0028	0.145	1.805	0.143	1.805
optimize a & 1/α	0.0043	0.139	2.128	0.139	2.128

جدول ۷: عوامل معادله Elovich برای دو کاتالیست.

Catalyst	A (1/min)	Ea (kJ/mol)	b1	b2	X <sub>∞</sub>
Reform.	5.60E 9	68.62	0.098	0.154	0.98
N. Acid	5.60E 9	68.62	0.116	0.150	0.97

$$1/\alpha = b_2 - b_1(S/L)$$

$$\frac{d\left(\frac{X}{X_\infty}\right)}{dt} = (5.60 \times 10^9 e^{-\frac{68.62E3}{RT}}) e^{(0.116(\frac{S}{L}) - 0.150)\frac{X}{X_\infty}} \quad ( )$$

$$D_p < 106 \mu m$$

### نتیجه‌گیری

( Aqua Regia)

SCM HDM

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( Jafarifar, 2005) ( Barakat, 2004)

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$$\frac{d\left(\frac{X}{X_\infty}\right)}{dt} = (5.60 \times 10^9 e^{-\frac{68.62E3}{RT}}) e^{(0.098(\frac{S}{L}) - 0.154)\frac{X}{X_\infty}} \quad ( )$$

J/mol.K	:R	فهرست علائم
kg	:S	(1/min) Frequency Factor :A
K	:T	( 1/min) :a
min	:t	S/L 1/α :b1,b2
	:X	(μm) :Dp
	:X <sub>∞</sub>	(kJ/mol) :Ea
Elovich	:α	kg :L

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