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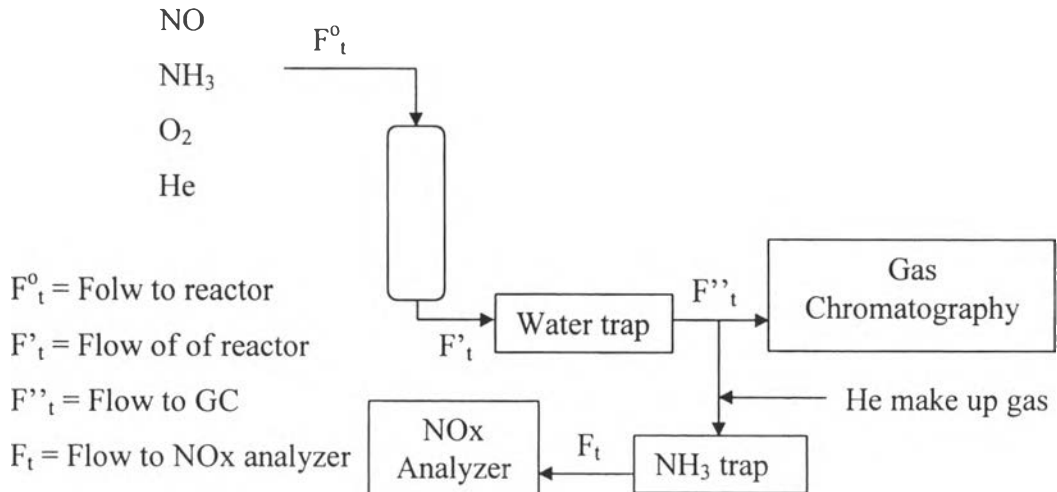
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APPENDIX A

Calculation of NO conversion and N₂ selectivity



1. NO Conversion

$$\text{NO Conversion} = \frac{y_{NO}^o F_t^o - y_{NO}' F_t'}{y_{NO}^o F_t^o}$$

2. N₂ Selectivity and N₂O selectivity

water amount produced per run = **A** g (from experiment)

$$\text{volume of water produced} = \frac{\mathbf{A} \text{ g} \cdot 0.0821 \text{ Latm/molK} \cdot 623\text{K}}{18 \text{ g/mol} \cdot 1\text{atm}}$$

$$= \mathbf{B} \text{ Litre}$$

$$\text{volume of water produced per min} = \frac{\mathbf{B} \text{ g} \cdot 1000 \text{ cm}^3}{\text{time run (min)}}$$

$$= \mathbf{C} \text{ cm}^3 / \text{min}$$

O₂ balance In reactor = Out reactor

$$2y_{O_2}^o F_t^o = 2y_{O_2}' F_t' + y_{NO}' F_t' + y_{N_2O}' F_t' + y_{H_2O}' F_t'$$

$$y_{N_2O}' = 2y_{O_2}^o \frac{F_t^o}{F_t'} - 2y_{O_2}' - y_{NO}' - y_{H_2O}'$$

$$\text{N}_2 \text{ selectivity} = \frac{\text{mole N}_2 \text{ produced}}{\text{mole NO converted}}$$

$$\text{N}_2 \text{ selectivity} = \frac{y_{\text{N}_2}'}{y_{\text{NO}}^o \frac{F_i^o}{F_i'} - y_{\text{NO}}'}$$

$$\text{H}_2\text{O selectivity} = \frac{y_{\text{H}_2\text{O}}'}{y_{\text{NO}}^o \frac{F_i^o}{F_i'} - y_{\text{NO}}'}$$

$$\text{N}_2\text{O selectivity} = \frac{y_{\text{N}_2\text{O}}'}{y_{\text{NO}}^o \frac{F_i^o}{F_i'} - y_{\text{NO}}'}$$

APPENDIX B

Raw data

Table B.1 The d-spacing of all catalysts

Types of pillared clay	$2\Theta(^{\circ})$	d-spacingd (Å)
1. TA clay		
- fresh	6.16	14.33
- dried	6.16 / 6.32*	14.33 / 13.97*
- calcined 350 °C 6hr	6.16 / 6.2*	14.33 / 14.24*
2. Fe TA clay		
2.1 Fe TA clay Imp1		
- calcined 350 °C 6hr	6.16 / 9.36*	14.33 / 9.44*
2.2 Fe TA clay Imp 2		
- calcined 350 °C 6hr	6.16 / 34.34*	14.33/2.61*
3. V clay		
- fresh	7.56	11.68
- dried	7.56 / 8.68*	11.68 / 10.18*
- calcined 350 °C 6hr	7.56 / 18.76*	11.68 / 4.73*
4. Fe V clay		
4.1 Fe V clay Ion		
- calcined 350 °C 6hr	7.56 / 34.78*	11.68 / 2.57*
4.2 Fe V clay Imp1		
- calcined 350 °C 6hr	7.56 / 34.6*	11.68 / 2.59*
4.3 Fe V clay Imp 2		
- calcined 350 °C 6hr	7.56 / 34.98*	11.68 / 2.56*
5. Mo clay		
- fresh	7.08	12.47
- dried	7.08 / 9.6*	12.47 / 9.21*
- calcined 350 °C 6hr	7.08 / 9.48*	12.47 / 9.32*

Table B.1 continued

Types of pillared clay	$2\Theta(^{\circ})$	d-spacing (\AA)
6. Fe Mo clay		
6.1 Fe Mo clay Ion - calcined 350 °C 6hr	7.08 / 61.2*	12.47 / 1.51*
6.2 Fe Mo clay Impl - calcined 350 °C 6hr	7.08 / 8.58*	12.47 / 10.29*
6.3 Fe Mo clay Imp 2 - calcined 350 °C 6hr	7.08 / 14.38*	12.47 / 6.15*
7. Mo V clay		
- fresh	9.08	9.73
- dried	9.08 / 9.56*	9.73 / 9.24*
- calcined 350 °C 6hr	9.08 / 14.92*	9.73 / 5.93*
8. Fe Mo V clay		
8.1 Fe Mo V clay Ion - calcined 350 °C 6hr	9.08 / -*	9.73 / -*
8.2 Fe Mo V clay Impl - calcined 350 °C 6hr	9.08 / 9.36*	9.73 / 9.44*
8.3 Fe Mo V clay Imp 2 - calcined 350 °C 6hr	9.08 / 9.48*	9.73 / 9.32*

NOTE : * means first peak observed

: All catalysts show d-spacing at $6.16^{\circ} = 14.33 \text{ \AA}$

: Mo V clay also show the same value of d-spacing of V clay and Mo clay at 7.56° and 7.08°

Table B.2 BET characterization

Catalysts	Surface area^a (m²/g)	Pore volume^b (cc/g)	Average Pore diameter (Å)
TA-clay	68.51	0.12370	72.25
Fe-TA-clay Imp1	84.90	0.11530	54.33
Fe-TA-clay Imp2	102.3	0.12740	49.81
V-clay	49.50	0.07248	63.09
Fe-V-clay Ion	83.53	0.13180	63.13
Fe-V-clay Imp1	116.10	0.13420	46.25
Fe-V-clay Imp2	99.97	0.12830	51.32
Mo-clay	39.45	0.04229	42.88
Fe-Mo-clay Ion	110.6	0.1862	67.34
Fe-Mo-clay Imp1	59.27	0.06172	41.65
Fe-Mo-clay Imp2	48.00	0.06916	57.03
Mo-V-clay	48.23	0.04932	40.90
Fe-Mo-V-clay Ion	73.73	0.12960	70.30
Fe-Mo-V-clay Imp1	75.03	0.05821	41.72
Fe-Mo-V-clay Imp2	73.25	0.10100	55.15

a : from 5 points BET

b : Total pore volume for pores with diameter less than 388.8 Å at $P/P^0 = 0.948$

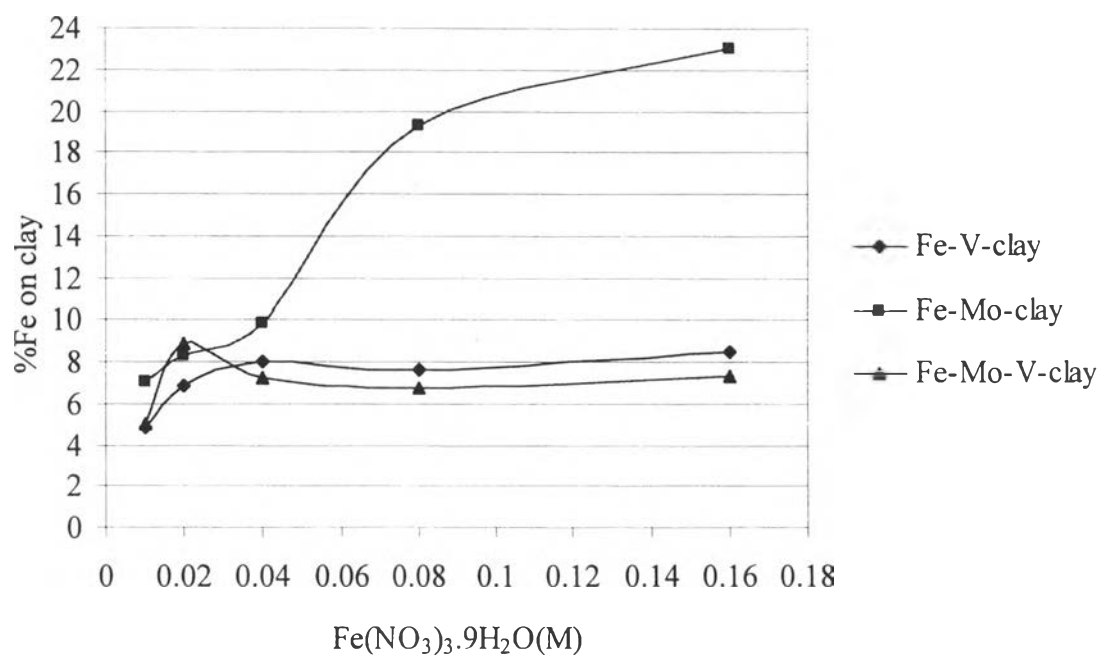


Figure B.1 Amount of iron on clay by atomic adsorption spectroscopy.

Table B.3 Activity Test of TA-clay calcined 350 °C 12 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	64.9	41.7	58.3	0
30	64.3	40.5	59.5	0
45	64.5	40.5	59.5	0
60	64.3	45.0	55.0	0
75	64.3	49.6	50.4	0
105	64.2	47.9	52.1	0
135	64.3	53.8	46.2	0

Table B.4 Activity Test of V-clay calcined 350 °C 12 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	59.3	62.0	38.0	0
30	65.2	62.4	37.6	0
45	64.5	62.8	37.2	0
60	64.5	63.1	36.9	0
75	64.5	61.9	38.1	0
105	64.5	61.1	38.9	0
135	64.5	57.6	42.4	0

Table B.5 Activity Test of Mo-clay calcined 350 °C 12 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	61.3	13.7	86.3	0
30	62.6	29.2	70.8	0
45	63.3	26.5	73.5	0
60	62.2	28.6	71.4	0
75	63.0	33.4	66.6	0
105	62.6	25.6	74.4	0
135	63.0	23.9	76.1	0

Table B.6 Activity Test of Mo-V-clay calcined 350 °C 12 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	75.9	36.1	73.9	0
30	75.2	32.0	68.0	0
45	75.8	36.7	63.3	0
60	75.8	25.8	74.2	0
75	75.8	27.2	72.8	0
105	75.7	22.2	77.8	0
135	75.6	26.1	73.9	0

Table B.7 Activity Test of Fe-V-clay Ion calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	27.1	100	0	0
30	29.2	100	0	0
45	26.8	100	0	0
60	28.1	100	0	0
75	29.3	100	0	0
105	30.5	100	0	0
135	30.5	100	0	0

Table B.8 Activity Test of Fe-Mo-clay Ion calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	12.3	100	0	0
30	13.4	100	0	0
45	13.8	100	0	0
60	13.8	100	0	0
75	13.7	100	0	0
105	13.4	100	0	0
135	13.7	100	0	0

Table B.9 Activity Test of Fe-Mo-V-clay Ion calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	11.9	100	0	0
30	11.5	100	0	0
45	11.5	100	0	0
60	11.9	100	0	0
75	11.9	100	0	0
105	11.5	100	0	0
135	11.9	100	0	0

Table B.10 Activity Test of Fe-TA-clay Imp 1 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	12.1	100	0	0
30	15.4	100	0	0
45	7.6	100	0	0
60	7.6	100	0	0
75	7.8	100	0	0
105	8.7	100	0	0
135	8.7	100	0	0

Table B.11 Activity Test of Fe-V-clay Imp 1 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	3.6	100	0	0
30	5.3	100	0	0
45	5.6	100	0	0
60	8.2	100	0	0
75	7.4	100	0	0
105	7.4	100	0	0
135	7.4	100	0	0

Table B.12 Activity Test of Fe-Mo-clay Imp 1 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	2.7	100	0	0
30	5.8	100	0	0
45	5.5	100	0	0
60	6.1	100	0	0
75	6.1	100	0	0
105	6.1	100	0	0
135	6.1	100	0	0

Table B.13 Activity Test of Fe-Mo-V-clay Imp 1 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	1.3	100	0	0
30	3.1	100	0	0
45	2.5	100	0	0
60	4.3	100	0	0
75	2.7	100	0	0
105	4.1	100	0	0
135	3.9	100	0	0

Table B.14 Activity Test of Fe-TA-clay Imp 2 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	29.1	100	0	0
30	28.3	100	0	0
45	27.9	100	0	0
60	27.7	100	0	0
75	28.0	100	0	0
105	27.2	100	0	0
135	28.3	100	0	0

Table B.15 Activity Test of Fe-V-clay Imp 2 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	9.4	100	0	0
30	9.4	100	0	0
45	10.1	100	0	0
60	10.6	100	0	0
75	10.4	100	0	0
105	10.6	100	0	0
135	10.1	100	0	0

Table B.16 Activity Test of Fe-Mo-clay Imp 2 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	8.6	100	0	0
30	9.5	100	0	0
45	9.4	100	0	0
60	9.5	100	0	0
75	9.8	100	0	0
105	9.3	100	0	0
135	9.4	100	0	0

Table B.17 Activity Test of Fe-Mo-V-clay Imp 2 calcined 350 °C 6 hr

Time-on-stream (min)	% NO Conversion	% Selectivity		
		N ₂	N ₂ O	NO ₂
0	0	0	0	0
15	9.4	100	0	0
30	6.5	100	0	0
45	7.5	100	0	0
60	7.9	100	0	0
75	7.8	100	0	0
105	7.9	100	0	0
135	7.9	100	0	0

Table B.18 The SCR activity of unloaded and Fe-loaded pillared catalysts

Catalysts	NO conversion(%)	N ₂ selectivity (%)	N ₂ yield (%)
1. TA -clay	64.4	49.0	31.6
2. V-clay	64.6	61.6	39.8
3. Mo-clay	62.6	24.9	17.5
4. Mo-V-clay	75.5	25.3	19.1
5. Fe-V-clay Ion	27.4	100	27.4
6. Fe-Mo-clay Ion	13.4	100	13.4
7. Fe-Mo-V-clay Ion	10.1	100	10.1
8. Fe-TA-clay Imp1	9.7	100	9.7
9. Fe-V-clay Imp 1	6.4	100	6.4
10. Fe-Mo-clay Imp1	5.5	100	5.5
11. Fe-Mo-V-clay Imp 1	3.1	100	3.1
12. Fe-TA-clay Imp2	28.1	100	28.1
13. Fe-Vclay Imp 2	10.2	100	10.2
14. Fe-Mo-clay Imp 2	9.4	100	9.4
15. Fe-Mo-V-clay Imp 2	7.8	100	7.8

Note : Imp 1 = Fe impregnation on dried clay

Imp 2 = Fe impregnation on calcined clay

Ion exchange = Fe ion exchange on calcined clay

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