



REFERENCES

1. Marecot, P., Fakche, A., Kellal, B., Mabilon, G., Prigent, M., and Barbier, J., Propane and propene oxidation over platinum and palladium on alumina: Effects of chloride and water. App. Catal.: Environmental, 3 (1994), 283-294.
2. Trimm, D.L., App. Catal., 7 (1983), 249.
3. Skoglunch, M., Lowendahl, L.O., and Ottersted, J.E. Combination of platinum and palladium on alumina supports as oxidation catalysts., App. Catal., 77 (1991), 9-20.
4. Dumpelmann, R., Cout, N.W., and Trimm, D.L. The positive effect of hydrogen on the reaction of nitric oxide with carbon monoxide over platinum and rhodium catalyst. Catal. Letters, 32 (1995), 357-369.
5. Bart et al, Experimental comparison among hydrocarbons and oxygenated compounds for their elimination by three-way automotive catalysts., in Silver, R.G., Sawyer, J.E., and Summers, J.C., Catalytic control of air pollution mobile and stationary sources ACS symposium series, (1992), 495.
6. Mohinder et al, US Pat. 5,139,994 (Aug. 18, 1992), Ford Motor Company.
7. Ishikawa, A., Komai, S., Satsuma, A., Hattori, T., and Murakami, Y. Solid superacid as the support of a platinum catalyst for low-temperature catalytic combustion. App. Catal., 110 (1994), 61-66.

8. Obuchi, A., Ohi, A., Nakamura, M., Ogata, A., Mizuno, K., and Ohuchi, H., Performance of platinum-group metal catalysts for the selective reduction of nitrogen oxides by hydrocarbons. App. Catal. B:Env., 2 (1993), 71-80.
9. Zhang, G., Yamaguchi, T., Kawakami, H., and Suzuki, T. Selective reduction of nitric oxide over platinum catalyst in the presence of sulfur dioxide and excess oxygen, App. Catal. B:Env., 1 (1992), L15-L20.
10. Volter, J., Liest, G., Spindler, H., and Lieske, H., Role of metallic and oxidic platinum in the catalytic combustion of n-Heptane. J. Cat., 104 (1987), 375-380.
11. Barbier Jr., J., and Duprez, D. Reactivity of steam in exhaust gas catalysis I. steam and oxygen/steam conversions of carbon monoxide and of propane over Pt-Rh catalysts., App. Catal. B:Env., 3 (1993), 61-83.
12. Briot, P., Auroux, A., Jeries, D., and Primet, M. Effect of particle size on the reaction of oxygen-adsorbed platinum supported on alumina. App. Catal., 59 (1990), 141-152.
13. Burch, R. and Loader, P.K. Investigation of Pt/Al₂O₃ and Pd/Al₂O₃ catalyst for the combustion of methane at low concentrations. App. Catal. B:Env., 5 (1994), 149-164.
14. Svoronos, D.G., Grigoropoulou, H.P., and Philppopoulos, C. App. Catal. B:Env., 5 (1995), 319-328.

15. Wu, C. and Hammerle, H. Development of a low cost, thermally, stable, monolithic three-way catalyst system. Ind. Eng. Chem. Prod. Res. Dev., 22(1983), 559-565
16. Yu-yao, Y., and Kummer, J.J. Low-temperature support precious metal catalyst prepared by thermal transport., J. Catal., 106 (1987), 307-312.
17. Barbier, J., Bahloul, D., and Marecot, P. Effect of chloride on sintering of Pt/Al₂O₃ catalyst. Cat. Letters, 8 (1991), 327-334.
18. Byong, K. Cho. Performance of Pt/Al₂O₃ catalyst in automobile engine exhaust with oscillatory air/fuel ratio. Ind. Eng. Chem. Res., 27 (1988), 30-36.
19. Pannee, A., Removal of exhaust gases via autocatalysts. Master's Thesis, Chulalongkorn university (1995)
20. Heck, R.M., and Farrauto, R.J., Catalytic air pollution control: Commercial technology, (1995), 73-77.
21. Zeldovich, J., The Oxidation of Nitrogen in Combustion and Explosion. Acta Physiochim U.S.S.R., 21 (1946), 577-628.
22. Kummer, J., Catalyst for automobile emission control. Prog. Combust. Sci. 6 (1980), 177-199.
23. Searles, R., Car exhaust pollution: the role of precious metal catalyst in its control. Endeavor: New Series, 13 (1989), 2-7.
24. Viala, A. . Health effects of air pollutants emitted by vehicles. Pet. Tech. 351 (1993), 25-27.

25. AC Rochester Division, General Motors Corporation, Flint, Michigan. Vehicle emission control system and catalytic converter technology, General Motor Distribution Corporation : Singapore, (1991).
26. Automotive pollution control division, Air quality Bureau, Environment agency Air pollution and motor vehicle emission control in Japan. Tokyo: Automotive pollution control division, Air quality Bureau of the environment agency. (1980).
27. Taschner, K. Environmentalist's views on automotive exhaust gases. In A. Crucg.(ed), Catalysis and automotive pollution control II, (1991), 17-33.
28. Wie, J., Catalysis for motor vehicle emissions. In D.D. Eley, Pines, and B. Weisz(eds.), Advances in Catalysis, London: Academic Press, (1975), 57-125.
29. Wolfgang S, Presentation to NEPO/PTT 'Lead Phase Out: Problems and Solution', Bangkok Thailand, Degussa Co., Ltd, (1995).
30. Mooney, L., Exhaust Control, Automotive. Kirk-Othmer Encyclopedia of Chemical Technology, 9 (1994), 982-1022.
31. Heck, R.M., and Frarrauto, R.J., Catalytic air pollution control:Commercial technology, (1995), 17-24.
32. Komiyama, M., Design and Preparation of Impregnated Catalysts. Catalyst Reviews: Sci. Eng., 27 (1985), 342-372.
33. Kolb, W.B., Papadimitriou, A.A., Cerro, R., Leavitt, D.D., and Summers, The Ins and Outs of Coating Monolithic Structures, Journal of Chemical Engineering Progress, 89 (1993), 61-67.

34. Cybulski, A., and Moulin, J., Monolith in Heterogeneous Catalysis. Catalysis Reviews-Sci. Eng., 36 (1994), 179-270.
35. Zechall, R, Baumann, G., and Eisele, H., SAE (Soc. Automot. Eng.), Pap. No. 730566, (1973).
36. Satterfield, C.N. Heterogeneous Catalyst in Practice., (1980).
37. Simone, D.O., Kennelly, T., Brungard, N.L., and Farrauto, R.J., Appl. Cat., 70 (1991), 87.
38. Davis, R.E., US Pat. 4,087,384, (1978).
39. Harrison, Brain, and Diwell, F.A. US. Pat. 4,127,510, (1979).
40. Tauster, S.J., Fung, S.C., and Garten, R.L., J. Amer. Chem. Soc. 100 (1978), 170

APPENDIX A
SAMPLES OF CALCULATION

1. Preparation of 0.03% Pt/Al₂O₃ Catalysts with the Dry Impregnation Method

Reagent : - Platinum tetrammine dichloride(II) (Pt(NH₃)₄Cl₂.H₂O)

Molecular weight = 352.13 g.

- Chloroplatinic acid (H₂PtCl₆ . 6H₂O)

Molecular weight = 517.92 g.

(Atomic weight of Platinum = 195.08)

Support : - Alumina (γ-Al₂O₃) ; type KNH -3

Pore volume = 1.0 ml./ g.

From Sumitomo Aluminium Smelting Co.,Ltd.

- Alumina powder 5 μ

From Sumitomo Aluminium Smelting Co.,Ltd

Substrate : - Cordierite honeycomb monolith

Ceramic type 400 cell/in²

Volume 800 cm³

From N-COR Co., Ltd.

Calculation for prepared 0.03% Pt / Al₂O₃ (% by weight)

based on : 0.03%Pt/ γ -Al₂O₃ Catalyst Weight = 100 g.

assume : alumina support used is X grams. So that, the catalyst

100 grams would composed of

Platinum 0.03 g.

Alumina X g.

Then 0.03+X = 100 gram.

Support (X) = 99.97 gram.

The alumina support weight used for all preparations is 2 grams.

1. For Pt(NH₃)₄Cl₂ used as precursor salt.

$$\begin{aligned} \text{Platinum required} &= 2 \times 0.03 / 99.97 \text{ g.} \\ &= 6.0 \times 10^{-4} \text{ g.} \end{aligned}$$

Platinum (Pt) 6.0×10^{-4} g. was prepared from 25 ml. of the stock solution of Platinum tetrammine dichloride(II) which prepared by dissolving 1 g. of Pt(NH₃)₄Cl₂ in de-ionized water.

$$\begin{aligned} \text{Pt content in stock solution} &= 1 \times 195.08 / 352.13 \text{ g.} \\ &= 0.554 \text{ g.} \end{aligned}$$

Therefore:

$$\begin{aligned} \text{The required-solution} &= (6.0 \times 10^{-4}) \times (25 / 0.554) \text{ ml.} \\ &= 0.0271 \text{ ml.} \end{aligned}$$

2. For H₂PtCl₆ . 6H₂O used as precursor salt.

$$\begin{aligned} \text{Platinum required} &= 2 \times 0.03 / 99.97 \text{ g.} \\ &= 6.0 \times 10^{-4} \text{ g.} \end{aligned}$$

Platinum (Pt) 6.0×10^{-4} g. was prepared from 25 ml. of the stock solution of Chloroplatinic acid which prepared by dissolving 1 g. of H_2PtCl_6 in de-ionized water.

$$\begin{aligned} \text{Pt content in stock solution} &= 1 \times 195.08 / 517.92 \text{ g.} \\ &= 0.377 \text{ g.} \end{aligned}$$

Therefore:

$$\begin{aligned} \text{The required-solution} &= (6.0 \times 10^{-4}) \times (25 / 0.377) \text{ ml.} \\ &= 0.04 \text{ ml.} \end{aligned}$$

2. Calculation of metal active site on catalyst

$$\begin{aligned} \text{The weight of catalyst used} &= w \text{ g.} \\ \text{Area of CO peak after adsorption} &= A \text{ unit.} \\ \text{Average area of 0.18 cc. standard CO peak} &= B \text{ unit.} \\ \text{Amounts of CO adsorbed on catalyst} &= B - A \text{ unit.} \\ \text{Volume of CO adsorbed on catalyst} &= [(B - A) / B] \times 0.18 \text{ ml.} \\ \text{Volume of gas 1 mole at } 30^\circ\text{C} &= 24.86 \times 10^3 \text{ ml.} \\ \text{Mole of CO adsorbed on catalyst (mole)} &= [(B - A) / B] \times [0.18 / 24.86 \times 10^3] \end{aligned}$$

$$1 \text{ mole is } 6.02 \times 10^{23} \text{ molecule}$$

Then, Molecule of CO adsorbed on catalyst

$$= 7.24 \times 10^{-6} [(B - A) / B] \times [6.02 \times 10^{23}] \text{ molecules}$$

$$\text{Metal active site} = 4.36 \times 10^{18} \times [(B - A) / B] / w \text{ molecules of CO / g. of catalyst.}$$

Example of calculate active site of 0.03%Pt/Al₂O₃

CAT.1 (0.03%Pt/Al ₂ O ₃)	0.4	gram. was evaluated.
Area of CO peak after adsorption	= 8603	unit.
Average area of 0.18 ml. standard CO peak	= 9092	unit
Amount of CO adsorbed on catalyst	= (9092-8603)	unit.
Volume of CO adsorbed on catalyst	= (9092-8603)/9092x0.18	
	= 9.68x10 ⁻³	ml.

The adsorption CO condition was carried out at 30°C

$$\text{Then, Mole of CO adsorbed on catalyst} = (9.68 \times 10^{-3}) / (24.86 \times 10^{-3})$$

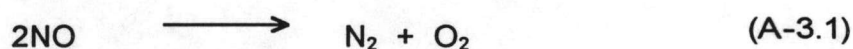
Molecule of CO adsorbed on catalyst (0.40 g.)

$$= (9.68 \times 10^{-3}) / (24.86 \times 10^{-3}) \times 6.02 \times 10^{23} = 2.344 \times 10^{17} \text{ molecules}$$

$$\text{Metal active site} = (2.344 \times 10^{17}) / (0.40) = 5.86 \times 10^{17} \text{ molecules/g. of catalyst}$$

3. Calculation of NO, CO and C₃H₈ conversion

The effluent gas was analyzed by gas chromatography, the NO reduction activity was evaluated in terms of the conversion of NO into N₂



$$\text{NO Conversion (\%)} = (2[\text{N}_2]_{\text{out}} / [\text{NO}]_{\text{in}}) \times 100 \quad (\text{A-3.2})$$

Where $[\text{NO}]_{\text{in}} = 500 \text{ ppm}$

$[\text{N}_2]_{\text{out}}$: analyzed by gas chromatography

From calibration curve (Figure A1)

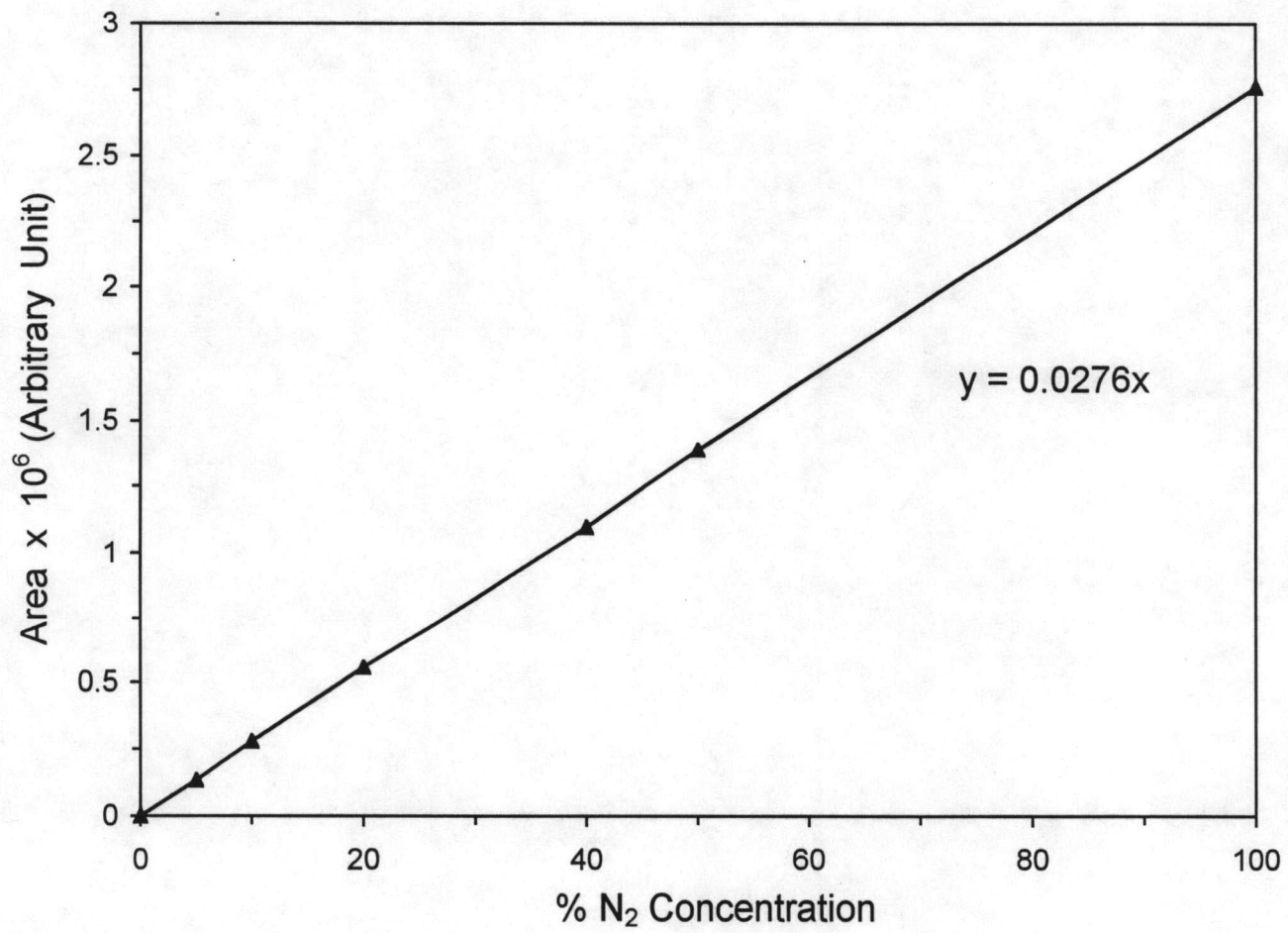


Figure A1 Calibration Curve of N₂ on GC-8APT

Area = area of N₂ peak on GC 8APT

Area x 10⁶ = 0.0276 x conc. of N₂ (%)

Area = 2.76 x 10⁴ x conc. of N₂ (%)

Area = 2.76 x conc of N₂ (ppm) ; (1 % = 10,000 ppm)

Thus, [N₂] = Area / 2.76

The CO oxidation activity was evaluated in terms of the conversion of CO into CO₂

$$\text{CO Conversion (\%)} = \frac{([\text{CO}]_{\text{in}} - [\text{CO}]_{\text{out}})}{[\text{CO}]_{\text{in}}} \times 100 \quad (\text{A-3.3})$$

The C₃H₈ oxidation activity was evaluated in terms of the conversion of C₃H₈ into CO₂ and H₂O.

$$\text{C}_3\text{H}_8 \text{ Conversion (\%)} = \frac{([\text{C}_3\text{H}_8]_{\text{in}} - [\text{C}_3\text{H}_8]_{\text{out}})}{[\text{C}_3\text{H}_8]} \times 100 \quad (\text{A-3.4})$$

APPENDIX B

CHEMICAL AND PHYSICAL PROPERTIES OF ALUMINA

Table B-1 Specification of Alumina Support (Al₂O₃) Type KNH-3

Chemical Composition (weight percent)		
-Al ₂ O ₃	60-70	%
-SiO ₂	30-35	%
-Fe ₂ O ₃	0.3-0.5	%
-TiO ₂	0.5-0.7	%
-CaO	0.1-0.2	%
-MgO	0.2-0.4	%
-Na ₂ O	0.3-0.4	%
-K ₂ O	0.2-0.3	%
-ZrO ₂ + HfO ₂	0.03-0.04	%

Physical Properties	
- Bulk density (g/ml.)	1.3 -1.5
- Apparent Specific Gravity	3.1-3.3
- Packing Density (lb./ft ³)	20-25
- Pore Volume (ml./g)	1.0-1.3
- Surface Area (m ² /g)	340-350

APPENDIX C

OPERATING CONDITION AND SAMPLES OF CHROMATOGRAM

1. A thermal conductivity detector gas chromatography (model 8APT) was used to analyze the concentrations of oxygen, nitrogen, carbon monoxide.

OPERATING CONDITIONS ARE AS FOLLOWS :

GC.	:	SHIMUDZU-GC-8APT
Detector	:	TCD.
Packed column	:	MS-5A
Carrier gas	:	Ultra high Purity Helium (99.999%)
Flow rate of Carries gas	:	30 ml./min
Column temperature	:	90 °C
Detector temperature	:	100 °C
Injector temperature	:	100 °C
Current	:	80 mA

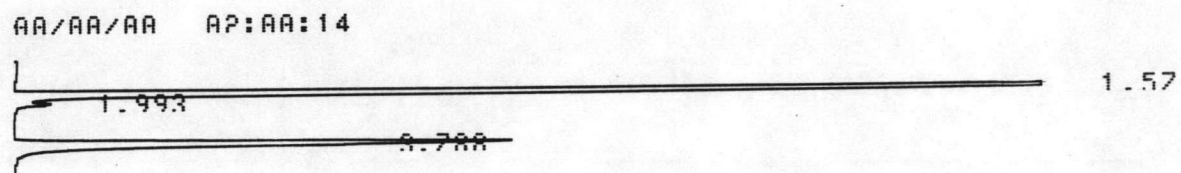
2. Gas chromatography model 8AIT was used to analyze the concentration of H₂O , propane, carbon dioxide.

Operating conditions were similar to model 8APT except :

Column packing	:	Porapak - Q
Carrier gas	:	High Purity Helium (99.99%)
Flow rate of Carrier gas	:	60 ml./min

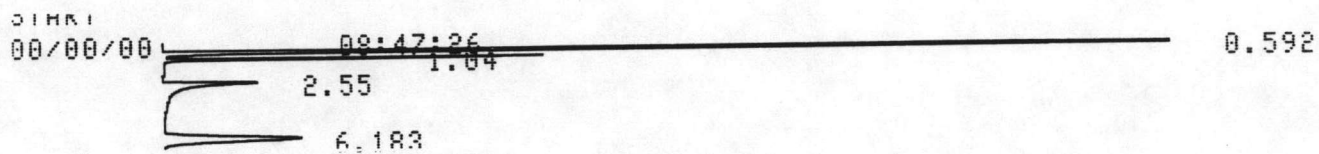
The samples chromatogram from gas analysis are shown in Figures B-1, B-2 respectively.

Figure C-1 Sample of Chromatogram from GC-8APT (column MS-5A)



PKNO	TIME	AREA	CONC	NAME
1.	1.570	31010	80.7297	OXYGEN
2.	1.993	176	0.4574	NITROGEN
3.	3.788	7227	18.8129	CARBON MONOXIDE
		-----	-----	
	TOTAL	38413	100	

Figure C-2 Sample of Chromatogram from GC-8AIT (column Porapak Q)



PKNO	TIME	AREA	CONC	NAME
1.	0.592	96386	93.2745	Air(N ₂ + O ₂)
2.	1.040	2170	2.0997	CO ₂
3.	2.550	1578	1.5269	H ₂ O
4.	6.183	3202	3.0989	PROPANE
		-----	-----	
	TOTAL	103336	100	



VITA

Mr. Chalermchai Sringangam was born on September 6, 1971. He received the Bachelor Degree of Chemical Engineering from Faculty of Engineering, Chulalongkorn University in 1994.