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APPENDIX A

SAMPLE OF CALCULATIONS

1. Preparation of 9%Ce-0.01%Rh-0.03%Pt/Al_2O_3 Catalyst with Incipient Impregnation Method

Reagent : Cerium (III) Nitrate [$Ce(NO_3)_3 \cdot 6H_2O$] ;

Purity 98% ; Molecular weight = 434.22,

manufactured by Wako Pure Chemical Industtries Co., Ltd.

(Atomic weight of cerium = 140.12)

Rhodium (III) Nitrate [$Rh(NO_3)_3$]

Purity 99.5% ; Molecular weight = 290.372 ;

manufactured by Wako Pure Chemical Industtries Co., Ltd.

(Atomic weight of rhodium = 102.91)

Chloroplatinic acid ($H_2PtCl_6 \cdot 6H_2O$)

Molecular weight = 517.92 ;

manufactured by PURE CHEMICAL INDUSTRIES Co., Ltd.

(Atomic weight of platinum = 195.1)

Support : Alumina (Al_2O_3) ; type KNH-3 ;

pore volume = 1.0 cc/g.

from Sumitomo Aluminium Smelting Co., Ltd.

Calculation for prepared 9wt%Ce-0.01wt%Rh-0.03wt%Pt catalyst

If the weight of alumina support used is X grams. So each 100 grams of the catalyst would compose of

Cerium	9		g.
Rhodium		0.01	g.
Platinum		0.03	g.
Alumina support		X	g.
Then 9 + 0.01 + 0.03 + X		= 100	g.
X		= 90.96	g.

Shown below is the calculation procedure of the amount of each ingredients for the required composition of the catalyst [Ce-Rh-Pt ; (9wt% : 0.01wt% : 0.03wt%)/Al_2O_3]

For 6 grams of alumina support used :

1) Cerium required = 6 x 9 / 90.96 g.

= 0.594 g.

Cerium (Ce) 0.594 g. prepared from the stock solution of cerium nitrate

= 0.594 x (25 / 3.162)

= 4.696 cc.

2) Rhodium required = 6-0.01 / 90.96 g.

= 6.596×10^{-4} g.

Rhodium (Rh) 6.596×10^{-4} g. prepared from the stock solution of rhodium nitrate = 6.596×10^{-4} x (50 / 0.1772) g.

= 0.186 cc.

3) Platinum required = 0.03 x 6 / 90.96 g.

= 1.98×10^{-3} g.

Platinum (Pt) 1.98×10^{-3} g. prepared from the stock solution of chloroplatinic acid = $1.98 \times 10^{-3} \times (25 / 0.3767)$ g.

= 0.131 cc.

As the pore volume of the alumina support is 1 cc/g., the total volume of impregnating solution that must by used is 6 cc. By the requirement of the incipient impregnate method, the distilled and de-ionized water is added to the above solution until the volume equals to the alumina pore volume 6 cc. This solution is used as the impregnating solution.

2. Calculation of metal active site on catalyst

Let the weiht of catalyst used = w g.

height of CO peak after adsorption = A unit

height of 0.18 ml standard CO peak = B unit

Amounts of CO adsorped on catalyst = B-A unit

Volume of CO adsorbed on catalyst = $[(B - A) / B] \times (0.18)$ ml.

Volume of gas 1 mole at 30 °C = 24.86×10^{3} mol.

Mole of CO adsorbed on catalyst = $[(B-A)/ B][0.18 / 24.86 \times 10^{3}]$ mole.

Molecule of CO adsorbed on catalyst

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

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

3. BET Surface Area Calculation. [45]

From BET equation :

$$x / v(1-x) = (1 / v_m C) + (C-1) \cdot x / v_m C \qquad \text{(A-4.1)}$$

where : x = ratio of partial pressure P/P_o

P_o = saturated vapor pressure of N_2 (or adsorbed gas)

P = equilibrium vapor pressure of N_2

v = amount of adsorption to cover the surface, c.c. at the NTP/gm of sample

$$C = \exp(E_1-E_2 / RT) \qquad \text{(A-4.2)}$$

where : E_1 = heat of adsorption of the first layer

E_2 = heat of condensation of adsorbed gas

assume $C \rightarrow \infty$, then

$$x / (v \cdot (1-x)) = (1 / v_m C) \cdot x \qquad \text{(A-4.3)}$$

let : $v_m = v'_m$

v_m = maen amount of adsorption to form the N_2 complete monolayer

v = amount of adsorption measuring by G.C.

$x = P / P_o$

$$P_b \cdot V / 273 = Pt\, V / T \qquad \text{(A-4.4)}$$

where : V = constant volume

P_b = pressure at 0 °C

P_t = pressure at t °C

T = 273.15 + t, K

P_b = (273.15 / T) · P_t = 1 atm

partial pressure

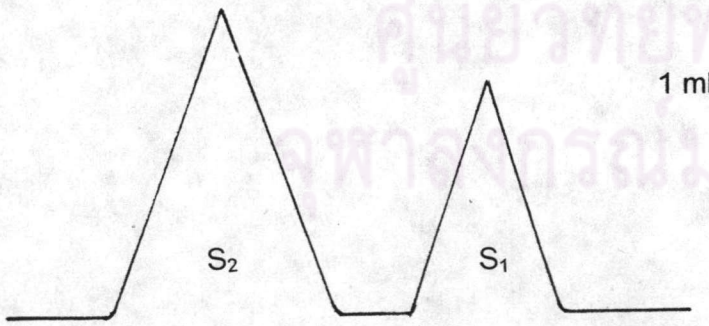
$$P = \frac{(\text{Flow of } (He + N_2) - \text{Flow of } He)}{\text{Flow of } (He + N_2)} \times Pb \qquad \text{(A-4.5)}$$

= 0.3 atm

N_2 saturated vapor pressure , P_o = 1.1 atm = 836 mm. Hg

$X = P/P_o = P / 1.1$

How to measure v



$$V = (s_2 / s_1) \times (1 / w) \times (273.15 / T) \times V \quad \text{c.c. / g of catalyst} \quad \text{(A-4.6)}$$

where : w = weight of sample

$$v'_m = \frac{v \times [\, 1- ((\text{flow of He} + N_2 - \text{flow of He}) / 1.1 \,]}{\text{flow of He} + N_2} \quad \text{c.c. NTP /g of catalyst} \quad \text{(A-4.7)}$$

$$s_b = s \times v'_m \quad \text{(A-4.8)}$$

where : s = surface area from literature of N_2

= 4.373 m^2/c.c of N_2

so that : s_b = 4.373 x v'_m m^2 / g of catalyst

4. Calculation of NO, CO and C_3H_8 conversion

The effiuent gas was analyzed by gas chromatography, the NO reduction activity was evaluated in terms of the conversion of NO into N_2.

NO Conversion(%) = (2 $[N_2]_{out}$ / $[NO]_{in}$) x 100

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

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

The C_3H_8 oxidation activity was evaluated in terms of the conversion of C_3H_8 into CO and CO_2.

$$C_3H_8 \text{ Conversion}(\%) = \frac{([C_3H_8]_{in} - [C_3H_8]_{out})}{[C_3H_8]_{in}} \times 100$$

APPENDIX B

Physical Properties of Carbon Monoxide

Property	Value
mol. wt.	28.011
m.p.	68.09 K
b.p.	81.65 K
H, fusion (68 K)[a]	0.867 kJ/mol
H, vaporization (81 K)[a]	6.042 kJ/mol
density [273 k, 101.33 kPa(1atm)]	1.2501 g/L
sp. gr., liquid, 79 K[b]	0.814
sp. gr., gas, 298 K[c]	0.968
critical temperature	132.9 K
critical pressure	3.496 Mpa(34.5 atm)
critical density	0.3010 g/cm^3
G^o formation (298 K)[a]	-137.16 kJ/mol
H^o formation (298 K)[a]	-110.53 kJ/mol
S^o formation (298 K)[a]	0.1975 kJ/mol
C_p^o (298 K)[a]	29.1 J/mol
C_v^o (298 K)[a]	20.8 J/mol
autoignition temperature	925 K
flammability limits in air[d]	
upper limit, %	74.2
lower limit, %	12.5

[a] To convert J to cal, divide by 4.184

[b] With respect to water at 277 K.

[c] With respect to air at 298 K.

[d] Saturated with water vapor at 290 K.

Physical Properties of Nitric Oxide

Property	Value
mol. wt.	30.1
m.p., °C	-161
b.p., °C	151.18
heat of fusion, kcal./mole	0.550
heat of vaporization, kcal./mole	3.293
heat of formation, kcal./mole	21.50
density[0 °C, 1 atm], g/L	1.2536
sp. gr., gas, [0 °C, 1 atm], (air = 1)	-93
critical temperature, °C	1.018
critical pressure, atm	64
color	colorless gas, blue liquid and solid

Ambient Air Quality Standard of Thailand(1981)

Pollutants	average value (mg/m^3)				methods of measurement
	1h	8 h	24 h	1 year	
Carbon Monoxide (CO)	50	20	-	-	Non Dispersive Infrared Detection
Nitrogen Dioxide (NO_2)	0.32	-	-	-	Gas Phase Chemiluminescence
Sulfur Dioxide (SO_2)	-	-	0.3	1*	Pararosanniline
Suspended Particulate Matter (SPM)	-	-	0.33	0.1*	Gravimetric
Photochemical Oxidant (O_3)	0.20	-	-	-	Chemiluminescence
Lead (Pb)	-	-	0.01	-	Wet Ashing

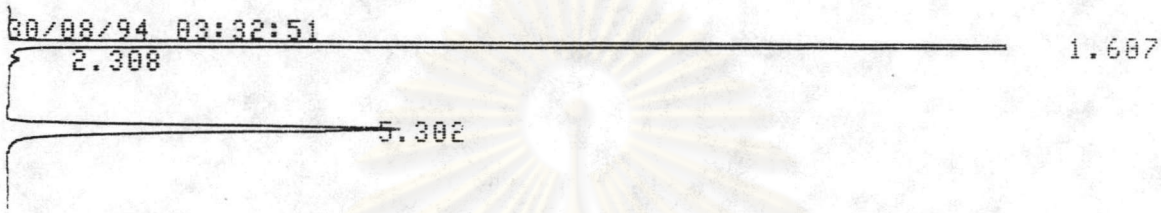
Note : * = Geometric mean

Specification of Alumina Support (Al_2O_3) Type KHN-3
from Sumitomo Aluminium Smelting Co., Ltd.

Chemical Composition (weight percent)		
- Al_2O_3	60-70	%
- SiO_2	30-35	%
- Fe_2O_3	0.3-0.5	%
- TiO_2	0.5-0.7	%
- CaO	0.1-0.2	%
- MgO	0.2-0.4	%
- Na_2O	0.3-0.4	%
- K_2O	0.2-0.3	%
- ZrO_2 + HfO_2	0.03-0.04	%

Physical Properties	
- Bulk Density (g/cc)	1.3-1.5
- Apparent Specific Gravity	3.1-3.3
- Packing Density (lb/ft^3)	20-25
- Pore Volume (cc/g)	0.5513
- Surface Area (m^2/g)	319.8757

Sample of Chromatogram



COLUMN MS-5A

PKNO	TIME	AREA	CONC.	NAME
1	1.607	28841	77.4407	O_2
2	2.308	86	0.2317	N_2
3	5.302	8315	22.3276	CO

COLUMN PORAPAK-Q

PKNO	TIME	AREA	CONC.	NAME
1	0.557	4239	34.7166	AIR
2	1.012	5517	40.4131	CO_2
3	2.417	1981	14.5087	H_2O
4	6.115	1414	10.3616	C_3H_8

VITA

Miss Pannee Asavapitchyont was born in Bangkok, Thailand on January 4, 1967. She received her Bachelor Degree of Science from Department of Chemistry, Faculty of Science, Srinakarinwiroj Prasarnmirt University in 1990.