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# APPENDIX

# APPENDIX A

## SAMPLE OF CALCULATIONS

### A-1 Calculation of Si/Metal Atomic Ratio for ZSM-5 and Cu-silicate

The calculation is based on weight of Sodium Silicate ($Na_2O \cdot SiO_2 \cdot H_2O$) in B1 and B2 solutions.

M.W. of Si = 28.0855

M.W. of $SiO_2$ = 60.0843

Weight percent of $SiO_2$ in Sodium Silicate = 28.5

M.W. of Al = 26.9815

M.W. of $AlCl_3$ = 133.3405

Weight percent purity of $AlCl_3$ = 97

M.W. of Cu = 63.54

M.W. of $Cu(NO_3)_2 \cdot 3H_2O$ = 241.60

Weight percent purity of $Cu(NO_3)_2 \cdot 3H_2O$ = 99.5

For example, to prepare ZSM-5 at Si/Al atomic ratio of 50. Using Sodium Silicate 69 g with 45 g of water as B1 solution.

$$\text{mole of Si used} = \frac{\text{wt. (\%)}}{100} \cdot \frac{\text{(M.W. of Si)}}{\text{(M.W. of } SiO_2\text{)}} \cdot \frac{\text{(1 mole)}}{\text{(M.W. of Si)}} \qquad \text{(A-1.1)}$$

$= 69 \cdot (28.5/100) \cdot (1/60.0843)$

$= 0.3273$

Si/Al atomic ratio = 50

mole of $AlCl_3$ required = $0.3273/50 = 6.5458 \cdot 10^{-3}$ mole

amount of $AlCl_3$ = $6.5458 \cdot 10^{-3} \cdot 133.34\ (100/97)$

= 0.8998 g

This is the amount of $AlCl_3$ used in A1 and A2 solutions

Si/Cu atomic ratio = 50

mole of $Cu(NO_3)_2 \cdot 3H_2O$ required = $0.3273/50 = 6.5458 \cdot 10^{-3}$ mole

amount of $Cu(NO_3)_2 \cdot 3H_2O$ = $6.5458 \cdot 10^{-3} \cdot 241.60 \cdot (100/99.5)$

= 1.5894 g

This is the amount of $Cu(NO_3)_2 \cdot 3H_2O$ used in A1 and A2 solutions.

**A-2 Calculation of Metal Ion-exchanged ZSM-5 and Metallosilicate**

Cu ion-exchange

Determine the amount of Cu into catalyst = 0.2 wt.%

the catalyst use = x g

So that : from the equation

$Cu/(x+Cu) = 0.2/100$

$100 \cdot Cu = 0.2 \cdot (x+Cu)$

$$(100\text{-}0.2)\cdot Cu = 0.2\cdot x$$

thus $$Cu = 0.2\cdot x/(100\text{-}0.2)\ g$$

use $Cu(NO_3)_2 3H_2O$ (M.W. 241.60, 26.30%Cu, purity 99.5%)

weight of $Cu(NO_3)_2 3H_2O$ = $[0.2\cdot x/(100\text{-}0.2)]\cdot[(100/26.30)\cdot(100/99.5)]$

**A-3 Calculation of Reaction Flow Rate**

The catalyst used = 0.50 g

packed catalyst into quartz reactor (diameter = 0.6 cm)

determine the average high of catalyst bed = x cm

So that, volume of catalyst bed = $\pi * (0.3)^2 \cdot x$ ml-catalyst

used GHSV (Gas Hourly Space Velocity) = 4,000 $h^{-1}$

$$GHSV = \frac{\text{Volumetric flow rate}}{\text{Volume of Catalyst}} = 4{,}000\ h^{-1}$$

Volumetric flow rate = 4,000 · Volume of catalyst

= 4,000 · $\pi$ ( 0.3)$^2$ ·x ml/h

= 4,000 · $\pi$ ( 0.3)$^2$ ·x / 60 ml/ min

at STP : Volumetric flow rate = Volume flow rate · $\frac{(273.15+t)}{273.15}$

where : t = room temperature, °C

## A-4 Calculation of NO and $C_3H_8$ conversion

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

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

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

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

## APPENDIX B

## 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 |

## APPENDIX C

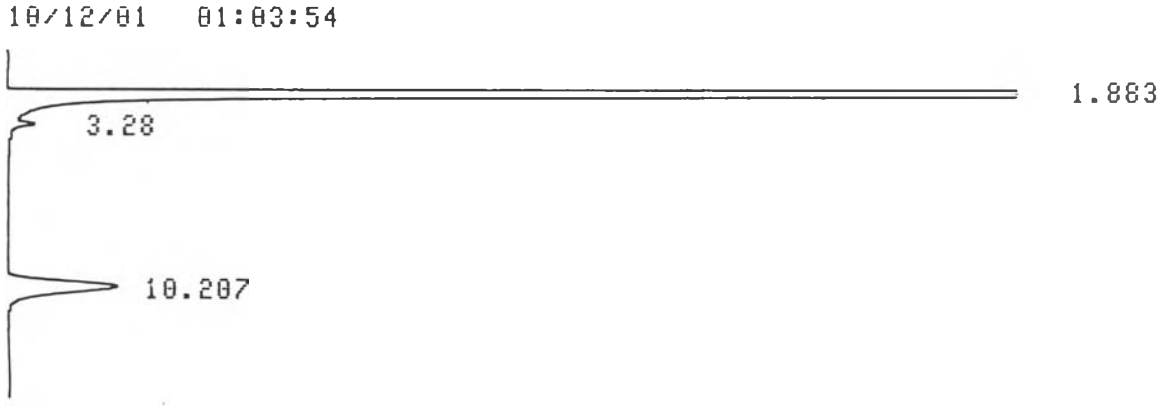
## AMBIENT AIR QUALITY STANDARD OF THAILAND (1981)

| Pollutants | average value ($mg/m^3$) | | | | methods of |
|---|---|---|---|---|---|
| | 1 h | 8 h | 24 h | 1 year | measurement |
| 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

## APPENDIX D

## SAMPLE OF CHROMATOGRAMS




COLUMN MS-5A

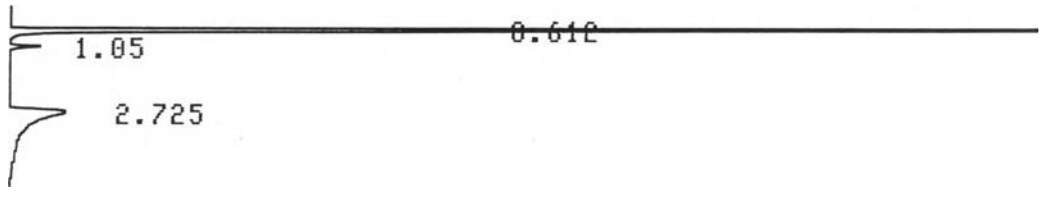
| PKNO | TIME | AREA | CONC | NAME |
|---|---|---|---|---|
| 1 | 1.883 | 213659 | 98.1127 | $O_2$ |
| 2 | 3.28 | 348 | 0.1597 | $N_2$ |
| 3 | 10.207 | 3691 | 1.6948 | CO |


COLUMN PORAPAK-Q

| PKNO | TIME | AREA | CONC | NAME |
|---|---|---|---|---|
| 1 | 0.553 | 60275 | 89.9274 | AIR |
| 2 | 1.02 | 1549 | 2.3108 | $CO_2$ |
| 3 | 2.495 | 2191 | 3.2683 | $H_2O$ |
| 4 | 6.188 | 3012 | 4.4935 | $C_3H_8$ |


COLUMN VZ-10

| PKNO | TIME | AREA | CONC | NAME |
|---|---|---|---|---|
| 1 | 1.995 | 57115 | 100 | $C_2H_4$ |




COLUMN PORAPAK-QS

| PKNO | TIME | AREA | CONC | NAME |
|---|---|---|---|---|
| 1 | 0.612 | 11850 | 91.4212 | AIR |
| 2 | 1.05 | 120 | 0.925 | $CO_2$ |
| 3 | 2.725 | 992 | 7.6538 | $H_2O$ |

# VITA

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