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APPENDIX

Standard Analysis Chromatogram

The reference standard for gas products were analyzed by a Shimadzu GC-17A equipped with flame ionized detector (FID) with a capillary HP-PLOT/Al_2O_3 "S" deactivated column. It was found that the retention time of methane, ethane, ethylene, propane, propylene, butane, acetylene, 1-butene and i-butene are 1.4, 1.8, 2.6, 3.7, 6.7, 8.0, 9.9, 11.7 and 12.2 min, respectively (see Figure 4.1).

The reference standard for liquid products were analyzed by a HP-5890 equipped with flame ionized detector (FID) with HP-INNOWAX column. It was found that the retention time of acetaldehyde, propanal, acetone, methanol, ethanol, toluene, acetol, acetic acid, propanoic acid and glycerol are 2.7, 3.1, 3.3, 4.0, 4.4, 5.9, 10.6, 14.0, 16.3 and 27.9 min, respectively (see Figure 4.2).

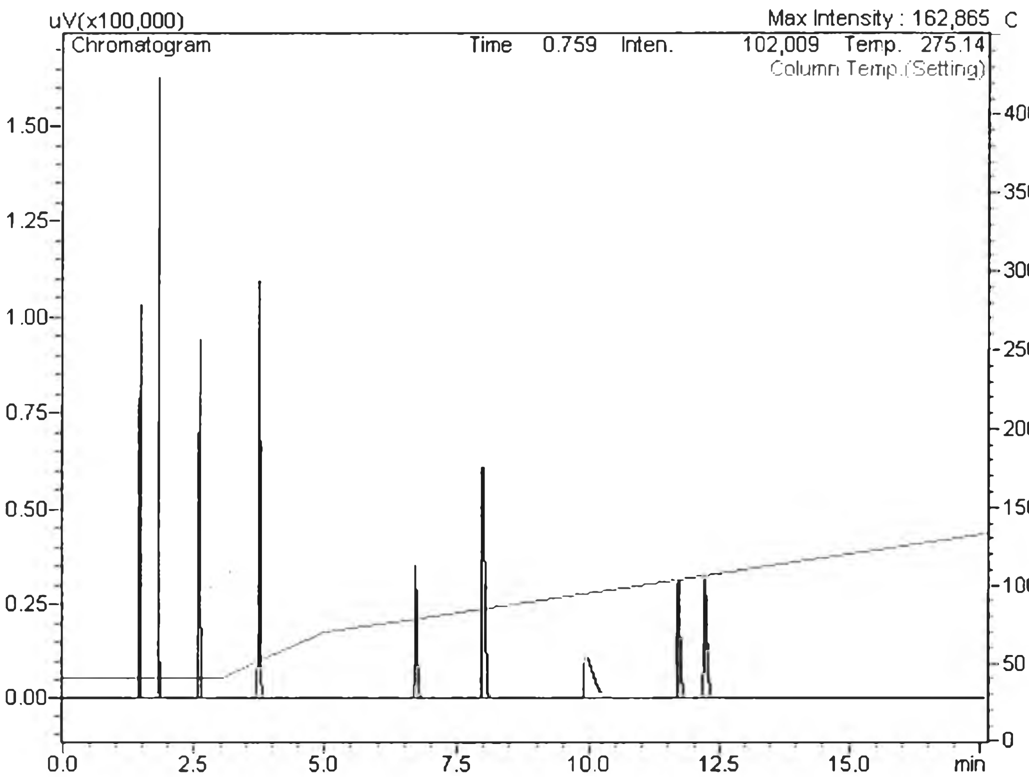

Figure A1 Chromatogram of standard gas mixture.

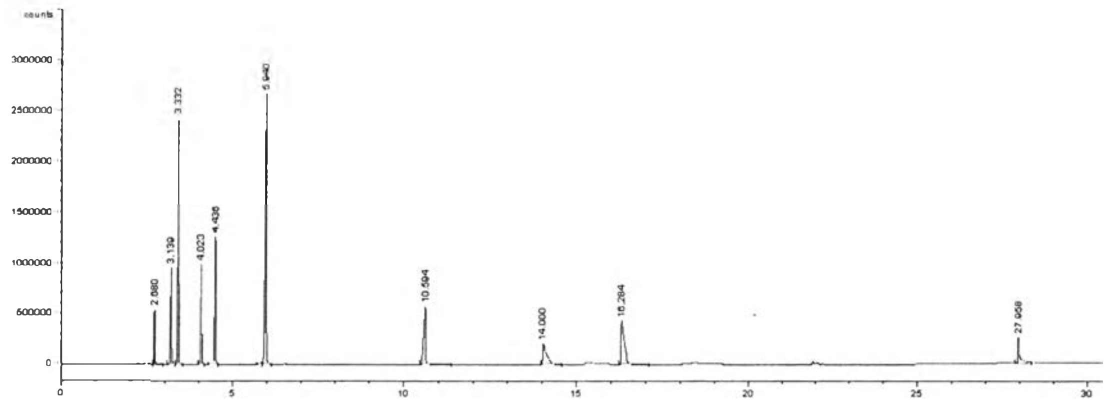

Figure A2 Chromatogram of standard liquid mixture.

To find out the response factor of each compound, n-octane was used as the reference. Table 4.1 shows the response factor of each substance in the reference standard which contains 1-propanol, propen-2-ol, methanol, ethanol, acetone, acetol, acetic acid, propionic acid and glycerol. For low boiling point compounds, it is difficult to obtain the response factor. For chemical standard, the response factors of propenal and propanal are assume to be equal to 1-propanol and the response factor of acetaldehyde is assume to be equal to ethanol.

Table A1 Response factors of each substance in the reference standard

Substances	Formula	Response factor
1-Propanol	C_3H_8O	0.651
Propen-2-ol	C_3H_6O	0.468
Methanol	CH_4O	0.355
Ethanol	C_2H_6O	0.521
Acetone	C_3H_6O	0.468
Acetol	$C_3H_6O_2$	0.293
Acetic acid	$C_2H_4O_2$	0.217
Propionic acid	$C_3H_6O_2$	0.504
Glycerol	$C_3H_8O_3$	0.501

Table A2 The product yields and conversion of glycerol obtained over the HZSM-5 with various SiO_2/Al_2O_3 ratios. (Reaction conditions: 400 °C, 300 psig, W/F= 1 h, and TOS=3 h)

SiO_2/Al_2O_3 ratios	23	30	50	80	280
Conversion (%)	100	100	100	100	100
Oxygenate (mol_{carbon} %)	*13.4*	*9.7*	*13.7*	*4.9*	*5.3*
Acetaldehyde	0.1	0.8	1.2	0.1	0.4
Formaldehyde	0.0	0.0	0.0	0.0	0.0
Propanal	0.0	1.4	1.8	0.0	0.0
Acetone	0.6	0.7	1.0	0.3	0.4
Propenal	0.0	0.2	0.2	0.0	0.0
Methanol	0.2	0.2	0.0	0.0	0.0
Ethanol	0.0	0.0	1.0	0.0	0.0
Alkyl alcohol	0.0	1.2	1.0	0.0	0.0
Acetol	0.0	0.0	0.0	0.0	0.0
Acetic	8.1	3.5	4.5	3.4	3.9
Propanoic	2.2	1.8	2.4	0.7	0.0
Heavy oxygenate	2.1	0.0	0.6	0.5	0.5
Hydrocarbon (mol_{carbon} %)	*86.6*	*90.3*	*86.3*	*95.1*	*94.7*
C1-C3 Paraffins	25.7	23.8	22.4	30.7	33.1
C4+ Paraffins	12.8	12.9	13.9	15.4	11.8
Ethylene	1.9	0.7	0.9	0.7	3.3
Propylene	1.6	0.4	0.6	0.5	4.2
Butene	3.6	0.0	0.0	0.0	1.5
Benzene	5.1	7.1	6.1	4.8	6.2
Toluene	14.9	19.7	18.1	15.1	14.1
EB	0.9	0.8	0.8	0.9	0.8
p-Xylene	3.1	3.9	3.7	3.7	2.5
m-Xylene	6.7	8.8	8.4	8.1	5.9
o-Xylene	3.1	3.9	3.7	3.7	2.7
C9Aromatics	3.9	4.9	4.2	5.8	3.8
C10Aromatics	0.5	0.6	0.6	1.3	0.4
C11Aromatics	1.6	1.6	1.2	2.8	3.0
C12Aromatics	1.0	1.0	1.3	1.0	1.0
C13Aromatics	0.2	0.3	0.5	0.5	0.4

Table A3 Product yield and acetaldehyde conversion over HZSM-5 with SiO_2/Al_2O_3 of 80 (Reaction conditions: 400 °C, 300 psig, and TOS = 3 h)

W/F (h)	0.1	0.5
Conversion (%)	72.6	98.6
Oxygenate (mol_{carbon} %)	*43.3*	*6.5*
Acetaldehyde	27.4	1.4
Formaldehyde	0.0	0.0
Propanal	1.4	1.4
Acetone	0.0	0.0
Propenal	0.0	0.0
Methanol	0.0	0.0
Ethanol	0.0	0.0
Alkyl alcohol	0.0	0
Acetol	0.0	0.0
Acetic	14.6	3.7
Propanoic	0.0	0.0
Heavy oxygenate	0.0	0.0
Hydrocarbon (mol_{carbon} %)	*56.7*	*93.5*
C1-C3 Paraffins	2.6	24.0
C4+ Paraffins	1.5	11.3
Ethylene	12.8	2.3
Propylene	17.4	0.9
Butene	0.0	0.0
Benzene	2.6	7.7
Toluene	7.4	26.1
EB	0.8	1.0
p-Xylene	1.3	2.9
m-Xylene	2.6	6.5
o-Xylene	1.2	2.9
C9Aromatics	4.3	5.8
C10Aromatics	0.7	0.7
C11Aromatics	0.5	0.8
C12Aromatics	0.4	0.2
C13Aromatics	0.6	0.2

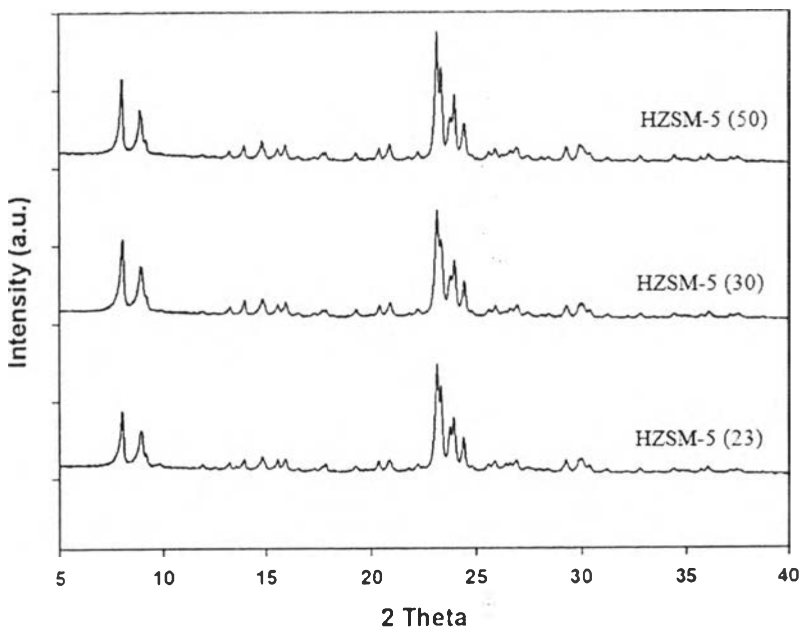

Figure A3 XRD patterns of HZSM-5 (23), HZSM-5 (30), HZSM-5, and (50) catalysts.

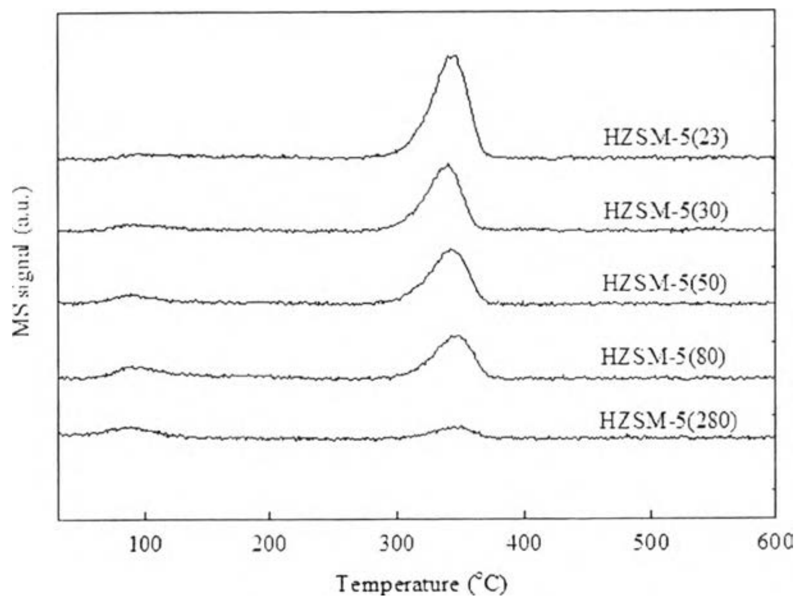

Figure A4 Isopropylamine-TPD profile of the parent HZSM-5 catalysts with SiO_2/Al_2O_3 ratios of 23, 30, 50, 80, and 280.

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Publications:

1. Tamiyakul, S.; Anutamjarikun, S.; and Jongpatiwut. S. (2016) The effect of Ga and Zn over HZSM-5 on the transformation of palm fatty acid distillate (PFAD) to aromatics. Catalysis Communications, 74, 49-54.
2. Tamiyakul, S.; Ubolcharoen, W.; Tungasmita, D.A.; and Jongpatiwut, S. (2015) Conversion of glycerol to aromatic hydrocarbons over Zn-promoted HZSM-5 catalysts. Catalysis Today, 256, 325-335.
3. Tamiyakul, S.; Sooknoi, T.; Lobban, L.L.; and Jongpatiwut, S., Generation of $(ZnH_3)^+$ species over hydrogen-treated Zn/HZSM-5 catalysts for *n*-pentane aromatization. (To be submitted to Journal of Molecular Catalysis A: Chemical).
4. Tamiyakul, S.; and Jongpatiwut, S., Improved *n*-pentane conversion and *p*-xylene selectivity using Zn(II)ions/Silicalite-1 coated on Zn/HZSM-5 catalysts (To be submitted to Catalysis Communications).
5. Tamiyakul, S.; Patharakul, C.; and Jongpatiwut, S., The effects of mixed MgO-Al_2O_3 supports in CuZnO/MgO-Al_2O_3 catalysts for the selective hydrogenolysis of biodiesel derived glycerol (To be submitted to Journal of Molecular Catalysis A: Chemical).

Presentations:

1. Tamiyakul, S.; Anutamjarikun, S.; and Jongpatiwut. S. (2015, May 14-15) The effect of Ga and Zn over HZSM-5 on the transformation of palm fatty acid distillate (PFAD) to aromatics. Poster presented at Southeast Asia Catalysis Conference 2015 (SACC 2015), National University of Singapore, Singapore.
2. Tamiyakul, S.; Ubolcharoen, W.; Tungasmita, D.A.; and Jongpatiwut, S. (2014, August 23-27) Conversion of glycerol to aromatic hydrocarbons over Zn-promoted HZSM-5 catalysts. Poster presented at 21st International Congress of Chemical and Process Engineering CHISA 2014, Prague, Czech Republic.

3. Tamiyakul, S.; and Jongpatiwut, S. (2014, April 22) Aromatization of glycerol over Zn/HZSM-5 catalysts. Oral presented at The 5th Research Symposium on Petroleum and Petrochemicals, and Advanced Materials and The 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand
4. Tamiyakul, S.; Sooknoi, T.; Lobban, L.L.; and Jongpatiwut, S., Generation of $(ZnH_3)^+$ species over hydrogen-treated Zn/HZSM-5 catalysts for *n*-pentane aromatization (Submitted to The 19th International Congress on Catalysis, Beijing, China).