REFERENCES

Abramova, A.V. (2010) Synthesis of ethylene and propylene on a SAPO-34 silica-alumina-phosphate catalyst. Catalysis in Industry, 2, 29-37.

Anderson, B.G., Schumacher, R.R., Duren, R., Singh, A.P., and Santen, R.A. (2002) Journal of Molecular Catalyst, 181, 291-301.

Arenamnart, S., and Trakarnpruk, W. (2006) Ethanol conversion to ethylene using metal-mordernite catalysts. Applied Science and Engineering, 2006, 21-32.

Baba, T., Inazu, K., Koyama, T., and Miyaji, A. (2008) Propylene production from ethylene and methane using silver and proton exchanged zeolite catalysts. Journal of the Japan Petroleum Institute, 51, 205-216.

Chen, J., Wright, P.A., Natarajan, S., and Thomas, J. M. (1994) Studies in Surface Science and Catalysis, 84, 1731-1737.

Chen, Y., Wu, Y., Tao, L., Dai, B., Yang, M., Chen, Z., and Zhu, X. (2010) Dehydration reaction of bio-ethanol to ethylene over modified SAPO catalysts. Journal of Industrial and Engineering Chemistry, 16, 717-722.

Cherubini, F. (2010) The biorefinery concept: Using biomass instead of oil for producing energy and chemicals. Journal of Energy Conversion and Management, 51, 1412–1421.

Corma, A., Melo, F.V., Sauvanaud, L., Ortega, F. (2005) Light cracked naphtha processing: controlling chemistry for maximum propylene production. Catalysis today, 107, 699–706.

Daisuke, G., Harada, Y., Furumoto, Y., Takahashi, A., Fujitani, T., Oumi, Y., Sadakene, M., and Sano, T. (2010) Conversion of ethanol to propylene over H-ZSM-5 types zeolites containing alkaline earth metals. Applied Catalysis, 283, 89-95.

Derouane, E.G., Nagy, J.B., Fernandez, C., Gabelica, Z., Laurent, E., and Maljean, P. (1988) Diffusion of alkanes in molecular sieves evidence for confinement effects. Applied Catalysis, 40, L1-L10.

Duan, C., Zhang, X., Zhou, R., Hua, Y., Zhang, Li., and Chen, J. (2013) Comparative studies of ethanol to propylene over HZSM-5/SAPO-34

catalysts prepared by hydrothermal synthesis and physical mixture. Fuel Processing Technology, 108, 31-40.

Dubois, D.R., Obrzut, D.L., Liu, J., Thundimadathil, J., Adekkanattu, P.M., Guin, J.A., Punnoose A., and Seehra, M.S. (2003) Conversion of methanol to olefins over cobalt, manganese and nickel incorporated SAPO-34 molecular sieves. Fuel Processing Technology, 83, 203-218.

Fatourehchi, N., Sohrabi, M., Royaee, S.J., and Mirarefin, S.M. (2010) Preparation of SAPO-34 catalyst and presentation kinetic model for methanol to olefin process. Chemical Engineering Research and Design, 89, 811-816.

Flanigan, E.M., Lok, B.M., Patton, R.L., and Wilson, S.T. (1986) New Developments in Zeolites Science and Technology. Study in Surface Science and Catalysis, 28.

Furumoto, Y., Harada, Y., Tsunoji, N., Takahashi, A., Fujitani, T., Ide, Y., Sadakane, M., and Sano, T. (2011) Effect of acidity of HZSM-5 zeolite on conversion of ethanol to propylene. Applied Catalysis A: General, 399, 262-267.

Gayubo, A.G., Alonso, A., Valle, B., Aguayo, V.T., and Bibao, J. (2010) Selective production of olefins from bioethanol on HZSM-5 zeolite catalysts treated with NaOH. Applied Catalysis B: Environmental, 97, 299–306.

Gayubo, A.G., Alonso, A., Valle, B., Aguayo, V.T., Olazer, M., and Bibao, J. (2010) Hydrothermal stability of H-ZSM-5 catalysts modified with Ni for the transformation of bio-ethanol into hydrocarbon. Fuel, 89, 3365-3372.

Goto, D., Harada, Y., Furumoto, Y., Takahashi, A., Fujitani, T., Oumi, Y., Sadakane, M., and Sano, T. (2010) Conversion of ethanol to propylene over HZSM-5 type zeolites containing alkaline earth metals. Applied Catalysis A: General, 383, 89–95.

Inaba, M., Murata, K., and Takahara, I. (2009) Effect of Fe-loading and reaction temperature on the production of olefins from ethanol by Fe/HZSM-5 zeolite catalysts. Reaction Kinetic Catalysis Letter, 97, 19-26.

Inoue, K., Inab, M., Takahara, I., and Murat, K. (2010) Conversion of ethanol to propylene by HZSM-5 with Si/Al_2 ratio of 280. Catalysis Letter, 136, 14-19.

Inui, T., and Kang, M. (1997) Reliable procedure for the synthesis of Ni-SAPO-34 as a highly selective catalyst for methanol to ethylene conversion. Applied Catalysis, 164, 211-223.

Kang, M. (2000) Methanol conversion on metal-incorporated SAPO-34. Journal of Molecular Catalysis, 160, 437-444.

Lin, B., Zhang, Q., and Wang, Y. (2009) Catalytic conversion of ethene to propene and butenes over H-ZSM-5. Industrial and Engineering Chemistry Research, 48, 10788–10795.

Makarfi, Y.I., Yakimova, M.S., Lermontov, A.S., Erofeev, V.I., Koval, L.M., and Tretiyakov, V.F. (2009) Conversion of bioethanol over zeolites. Chemical Engineering Journal, 154, 396-400.

McCusker, L.B., and Baerlocher, C. (2001) Zeolite structures. Study in Surface Science and Catalysis, 137, 37-67.

Morschbacker, A. (2009) Bio-ethanol based ethylene. Journal of Macromolecular Science, 49, 79-84.

Nawaz, Z., Tang, X., Zhang, Q., Wang D., and Fei W. (2009) SAPO-34 supported Pt–Sn-based novel catalyst for propane dehydrogenation to propylene. Catalysis Communications, 10, 1925–1930.

Niekerk, M.J.V., Fletcher, J.C.Q., and O'Connor C.T. (1996) Effect of catalyst modification on the conversion of methanol to light olefins over SAPO-34. Applied Catalysis, 138, 135-145.

Ogura, M., Shinomiya, S.Y., Tateno, J., Nara, Y., Nomura, M., Kikuchi, E., and Matsukata, M. (2001) Alkaline treatment technique—new method for modification of structural and acid-catalytic properties of ZSM-5 zeolites. Applied Catalysis A: General, 219, 33–43.

Oikawa, H., Shibata, Y., Inazu, K., Iwase, Y., Murai, K., Hyodo, S., Kobayashi, G., and Baba, T. (2006) Highly selective conversion of ethylene to propylene over SAPO-34 as a solid acid catalyst. Applied Catalysis A:General, 312, 181-185.

Ouyang, J., Kong, F., Su, G., Hu, Y., and Song, Q. (2009) Catalytic conversion of bio-ethanol to ethylene over La-modified HZSM-5 catalysts in a bioreactor. Catalysis Letter, 132, 64-74.

Phillips, C.B., and Datta, R. (1997) Production of ethylene from hydrous ethanol on H-ASM-5 under mild conditions. Industrial and Engineering Chemistry Research, 36, 4466-4475.

Saeed, M.H., (2003) Conversion of methanol to light olefins on SAPO-34: kinetic modeling and reactor design. Ph.D. Thesis, Texas A&M University, USA.

Saxton, C.G., Kruth, A., Castro, M., Wright, P.A., and Howea, R.F. (2010) Xenon adsorption in synthetic chabazite zeolites. Microporous and Mesoporous Materials, 129, 68-73.

Song, Z., Takahashi, A., Nakamura, I., and Fujitani, T. (2010) Phosphorus-modified HZSM-5 for conversion of ethanol to propylene. Applied Catalysis A: General, 384, 201-205.

Takahara, I., Saito, M., Inaba, M., and Murata, K. (2005) Dehydration of ethanol into ethylene over solid acid catalysts. Catalysis Letters, 105, 249-252.

Takahashi, A., Xia, W., Nakamura, I., Shimada, H., and Fujitani, T. (2012) Effects of added phosphorus on conversion of ethanol to propylene over ZSM-5 catalysts. Applied Catalysis, 423, 162-167.

Viswanadham, N., Saxena, S. K., Kumar, J., Sreenivasulu, P., and Nandan, D. (2012) Catalytic performance of nano crystalline H-ZSM-5 in ethanol to gasoline (ETG) reaction. Fuel, 95, 298-304.

Wang, X.Q., Xie C.G., Li Z.T., and Zhu G.Q. (Eds.). (2002) Catalytic processes for light olefin production. Beijing: Research Institute of Petroleum Processing, SINOPEC.

Water, L.G.A., Waal, J.C., Jansen, J.C., and Maschmeyer, T. (2004) Improved catalytic activity upon Ge incorporation into ZSM-5 zeolites. Journal of Catalysis, 223, 170–178.

Wei, Y.X., Zhang, D.Z, Xu, L., Chang, F.X., He, Y.L., Meng, S.H., Su, B.L., and Liu Z.M. (2008) Synthesis, characterization and catalytic performance of metal-incorporated SAPO-34 for chloromethane transformation to light olefins. Catalysis Today, 131, 262-269.

Weisz, P.B. (1980) Pure Applied Chemistry, 52, 2091.

Wilson, S., and Barger, P. (1999) The characteristics of SAPO-34 which influence the conversion of methanol to light olefins. Microporous and Mesoporous Matterials, 29, 117-126.

Wilson, S.T., Broach, R.W., Blackwell, C.S., Bateman, C.A., McGuire, N.K., and Kirchner, R.M. (1982) Microprorous and Mesoporous Materials, 28, 125-137.

Zavorotynska, O., Vitillo, J.G., Spoto, G., and Zecchina, A. (2011) Role of extra framework metal sites for hydrogen adsorption into the pores of a zeolite : FT-IR study. International Journal of Hydrogen Energy, 36, 7944-7950.

Zhang, H., Sun, K., Feng, Z., Ying, P., and Li, C. (2006) Studies on the SbOx species of SbOx/SiO2 catalysts for methane-selective oxidation to formaldehyde. Applied Catalysis A: General, 305, 110–119.

Zhao, L., Gao, J., Xu, C.M., and Shen, B.J. (2011) Alkali-treatment of ZSM-5 zeolites with different SiO2/Al2O3 ratios and light olefin production by heavy oil cracking. Fuel Processing Technology, 92, 414–420.

Zhang, L., Xu, C., and Champagne, P. (2010) Energy Conversion Management, 51, 969–982.

Zhang, X., Wang, R., Yang, X., and Zhang, F. (2008) Comparison of four catalysts in the catalytic dehydration of ethanol to ethylene. Microporous and Mesoporous Materials, 116, 210-215.

APPENDICES

Appendix A Gas Composition from Using Oxide-Doped SAPO-34

Table A1 Gas composition from using SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 420 min
Methane	0.07	0.04	0.04	0.04
Ethylene	98.14	98.73	98.78	98.91
Ethane	0.81	0.45	0.33	0.38
Propylene	0.24	0.20	0.19	0.19
Propane	0.02	0.01	0.01	0.01
Butylene	0.29	0.22	0.23	0.19
Butane	0.43	0.34	0.41	0.28
Total	100	100	100	100

Table A2 Gas composition from using 3% Ge in GeO_2/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	0.50	0.32	0.16	0.13
Ethylene	81.30	93.01	97.64	98.26
Ethane	0.25	1.29	0.61	0.50
Propylene	1.57	3.78	1.06	0.70
Propane	14.34	1.39	0.38	0.23
Butylene	0.45	0.05	0.05	0.06
Butane	1.60	0.16	0.11	0.11
Total	100	100	100	100

Table A3 Gas composition from using 5% Ge in GeO_2/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 240 min	@ 360 min	@ 420 min	@ 480 min
Methane	0.44	0.27	0.22	0.24
Ethylene	81.52	94.33	96.58	97.00
Ethane	2.05	1.08	0.83	0.82
Propylene	9.21	2.79	1.45	1.12
Propane	6.14	1.21	0.59	0.43
Butylene	0.13	0.08	0.09	0.11
Butane	0.51	0.24	0.24	0.29
Total	100	100	100	100

Table A4 Gas composition from using 3% Ga in Ga_2O_3/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	0.23	0.22	0.21	0.14
Ethylene	91.62	90.83	91.22	92.69
Ethane	1.42	0.98	1.24	0.73
Propylene	1.19	1.66	1.53	0.93
Propane	0.20	0.42	0.05	0.04
Butylene	3.04	2.65	2.27	2.62
Butane	2.28	3.24	3.48	2.84
Total	100	100	100	100

Table A5 Gas composition from using 5% Ga in Ga_2O_3/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	0.50	0.43	0.24	0.15
Ethylene	78.27	78.18	78.11	85.49
Ethane	2.45	1.74	1.03	0.62
Propylene	6.74	7.54	5.13	3.34
Propane	0.52	0.12	0.05	0.03
Butylene	6.06	6.12	9.17	6.10
Butane	5.46	5.87	6.26	4.27
Total	100	100	100	100

Table A6 Gas composition from using 3% Sn in SnO_2/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	2.22	1.47	1.60	1.53
Ethylene	82.28	81.30	85.29	85.40
Ethane	8.13	4.78	7.80	7.74
Propylene	5.18	10.84	4.02	4.10
Propane	0.43	1.06	0.14	0.09
Butylene	0.84	0.13	0.62	0.64
Butane	0.92	0.41	0.54	0.50
Total	100	100	100	100

Table A7 Gas composition from using 5% Sn in SnO_2/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	1.06	1.52	0.90	0.65
Ethylene	63.88	60.66	79.69	86.78
Ethane	3.42	4.51	2.24	1.78
Propylene	9.21	15.26	10.61	5.53
Propane	18.79	15.07	2.69	1.86
Butylene	0.61	0.58	1.31	1.26
Butane	3.03	2.41	2.55	2.14
Total	100	100	100	100

Table A8 Gas composition of 3% Sb in Sb_2O_3/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	1.05	1.43	0.66	0.57
Ethylene	86.74	82.45	90.31	90.98
Ethane	5.59	8.57	3.82	3.44
Propylene	1.98	2.64	1.73	1.71
Propane	0.19	0.85	0.08	0.06
Butylene	1.99	1.83	1.56	1.50
Butane	2.46	2.25	1.84	1.74
Total	100	100	100	100

Table A9 Gas composition of 5% Sb in Sb_2O_3/SAPO-34 catalyst as a function of time on stream

Component	Composition (wt%)			
	@ 120 min	@ 240 min	@ 360 min	@ 480 min
Methane	0.55	0.37	0.14	0.11
Ethylene	92.69	93.28	95.93	96.14
Ethane	2.95	1.57	0.86	0.71
Propylene	2.21	3.40	2.62	2.61
Propane	0.49	0.06	0.01	0.01
Butylene	0.38	0.48	0.22	0.22
Butane	0.74	0.84	0.22	0.20
Total	100	100	100	100

Appendix B Gas Composition from Using KOH-Treated HZSM-5 as Catalysts

Table B1 Gas composition from using HZSM-5 catalyst as a function of time on stream

Component	Composition (wt%)						
	@ 60 min	@ 120 min	@ 180 min	@ 240 min	@ 300 min	@ 360 min	@ 420 min
Methane	2.87	2.85	2.78	2.68	2.43	2.31	2.23
Ethylene	81.42	81.68	81.71	81.76	81.72	81.64	81.97
Ethane	5.56	5.42	5.37	5.37	5.12	5.03	4.92
Propylene	0.56	0.56	0.58	0.60	0.61	0.63	0.64
Propane	6.05	5.97	6.02	6.00	6.10	6.11	5.99
Butylene	0.15	0.15	0.15	0.16	0.17	0.18	0.18
Butane	3.39	3.37	3.38	3.45	3.85	4.09	4.06
Total	100	100	100	100	100	100	100

Table B2 Gas composition from using 0.1 M KOH-treated HZSM-5 catalyst as a function of time on stream

Component	Composition (wt%)						
	@ 60 min	@ 120 min	@ 180 min	@ 240 min	@ 300 min	@ 360 min	@ 420 min
Methane	1.81	2.18	2.19	2.74	2.18	1.52	1.45
Ethylene	82.18	76.73	77.76	73.33	78.71	84.55	86.03
Ethane	10.54	14.19	13.72	15.72	12.11	8.77	8.12
Propylene	2.51	2.44	2.60	3.49	3.07	2.29	2.20
Propane	0.62	1.76	1.07	1.71	0.98	0.71	0.39
Butylene	0.73	0.81	0.79	0.83	0.92	0.68	0.58
Butane	1.61	1.98	1.87	2.18	2.02	1.48	1.24
Total	100	100	100	100	100	100	100

Table B3 Gas composition from using 0.5 M KOH-treated HZSM-5 catalyst as a function of time on stream

Component	Composition (wt%)						
	@ 60 min	@ 120 min	@ 180 min	@ 240 min	@ 300 min	@ 360 min	@ 420 min
Methane	2.93	3.02	3.27	3.49	2.69	2.50	2.46
Ethylene	73.14	70.72	68.18	63.06	75.57	77.56	78.89
Ethane	21.27	23.39	25.04	28.99	19.31	17.63	16.46
Propylene	1.19	1.28	1.63	2.18	1.09	1.05	1.02
Propane	0.25	0.29	0.33	0.34	0.25	0.22	0.22
Butylene	0.21	0.22	0.28	0.41	0.18	0.18	0.16
Butane	1.02	1.09	1.27	1.53	0.91	0.86	0.80
Total	100	100	100	100	100	100	100

Table B4 Gas composition from using 0.9 M KOH-treated HZSM-5 catalyst as a function of time on stream

Component	Composition (wt%)						
	@ 60 min	@ 120 min	@ 180 min	@ 240 min	@ 300 min	@ 360 min	@ 420 min
Methane	0.72	0.55	0.50	0.50	0.43	0.41	0.40
Ethylene	89.76	92.54	93.65	94.27	95.04	95.48	95.75
Ethane	7.58	5.49	4.56	3.71	3.40	3.01	2.73
Propylene	0.95	0.72	0.68	0.83	0.62	0.61	0.62
Propane	0.18	0.14	0.13	0.15	0.11	0.10	0.11
Butylene	0.26	0.18	0.16	0.19	0.13	0.13	0.13
Butane	0.54	0.37	0.33	0.35	0.28	0.26	0.26
Total	100	100	100	100	100	100	100

APPENDIX C Product Distribution from using Oxides Loaded on SAPO-34 as a Catalyst

Table C1 Product distribution and product yields from using germanium oxide loaded on SAPO-34 as a catalyst

Catalyst	SA34	3GeSA34	5GeSA34
Ethanol conversion (wt %)	93.7	96.8	96.7
Feed ethanol (ml/hr)	1.97	1.97	1.97
Feed ethanol (g)	11.05	12.62	12.62
Converted ethanol (g)	10.36	12.20	12.20
Converted ethanol (g/h)	1.48	1.53	1.53
Product distribution (g)			
Total gas	7.65	11.20	10.83
Total extracted oil	0.00	0.42	0.52
Total liquid*	3.40	1.01	1.27
Product yield (wt %)			
Gas yield	69.22	88.68	85.79
Extracted oil yield	0.00	3.32	4.14
Liquid yield	30.78	8.00	10.06

* Water and chemical dissolved in water

Table C2 Product distribution and product yields from using gallium oxide loaded on SAPO-34 as a catalyst

Catalyst	SA34	3GaSA34	5GaSA34
Ethanol conversion (wt %)	93.7	97.1	96.9
Feed ethanol (ml/hr)	1.97	1.97	1.97
Feed ethanol (g)	11.05	12.62	12.62
Converted ethanol (g)	10.36	12.26	12.26
Converted ethanol (g/h)	1.48	1.53	1.53
Product distribution (g)			
Total gas	7.65	10.67	9.78
Total extracted oil	0.00	0.41	1.11
Total liquid*	3.40	1.54	1.74
Product yield (wt %)			
Gas yield	69.22	84.50	77.45
Extracted oil yield	0.00	3.29	8.79
Liquid yield	30.78	12.21	13.76

* Water and chemical dissolved in water

Table C3 Product distribution and product yields from using tin oxide loaded on SAPO-34 as a catalyst

Catalyst	SA34	3SnSA34	5SnSA34
Ethanol conversion (wt %)	93.7	96.8	96.9
Feed ethanol (ml/hr)	1.97	1.97	1.97
Feed ethanol (g)	11.05	12.62	12.62
Converted ethanol (g)	10.36	12.26	12.26
Converted ethanol (g/h)	1.48	1.53	1.53
Product distribution (g)			
Total gas	7.65	10.77	9.76
Total extracted oil	0.00	0.22	0.35
Total liquid*	3.40	1.63	2.52
Product yield (wt %)			
Gas yield	69.22	85.33	77.29
Extracted oil yield	0.00	1.72	2.74
Liquid yield	30.78	12.95	19.97

* Water and chemical dissolved in water

Table C4 Product distribution and product yields from using antimony oxide loaded on SAPO-34 as a catalyst

Catalyst	SA34	3SbSA34	5SbSA34
Ethanol conversion (wt %)	93.7	96.8	96.9
Feed ethanol (ml/hr)	1.97	1.97	1.97
Feed ethanol (g)	11.05	12.62	12.62
Converted ethanol (g)	10.36	12.26	12.26
Converted ethanol (g/h)	1.48	1.53	1.53
Product distribution (g)			
Total gas	7.65	11.13	9.83
Total extracted oil	0.00	0.35	1.07
Total liquid*	3.40	1.14	1.72
Product yield (wt %)			
Gas yield	69.22	88.15	77.88
Extracted oil yield	0.00	2.79	8.51
Liquid yield	30.78	9.06	13.61

* Water and chemical dissolved in water

APPENDIX D Product Distribution from Using KOH-Treated HZSM-5 as a Catalyst

Table D1 Product distribution and product yields from using KOH-Treated HZSM-5 as a catalyst

Catalyst	HZ5	0.1M KOH/HZ5	0.5M KOH/HZ5	0.9M KOH/HZ5
Ethanol conversion (wt %)	93.96	96.29	96.72	96.95
Feed ethanol (ml/hr)	1.97	1.97	1.97	1.97
Feed ethanol (g)	11.05	11.05	11.05	11.05
Converted ethanol (g)	10.38	10.64	10.68	10.71
Converted ethanol (g/h)	1.48	1.52	1.53	1.53
Product distribution (g)				
Total gas	7.85	6.77	6.31	6.78
Total oil	1.27	1.36	1.01	0.36
Total liquid*	1.92	2.92	3.73	3.90
Product yield (wt %)				
Gas yield	71.10	61.26	57.08	61.37
Oil yield	11.48	12.31	9.11	3.30
Liquid yield	17.42	26.42	33.81	35.33

* Water and chemical dissolved in water

APPENDIX E True Boiling Point Curves

Table E1 True boiling point curves of oil from using germanium oxide-doped SAPO-34 as a catalyst

%OFF	Boiling point (°C)	
	3GeSA34	5GeSA34
0	50.9	51.1
5	52.0	52.6
10	53.1	53.7
15	54.1	54.8
20	55.2	55.9
25	56.3	56.9
30	57.4	58.0
35	58.4	59.1
40	59.5	60.1
45	60.6	61.2
50	61.7	62.3
55	62.7	63.4
60	63.8	64.4
65	64.9	65.9
70	65.9	91.1
75	67.0	163.0
80	68.1	223.6
85	69.2	246.9
90	70.2	250.4
95	100.4	327.1
100	458.8	500.0

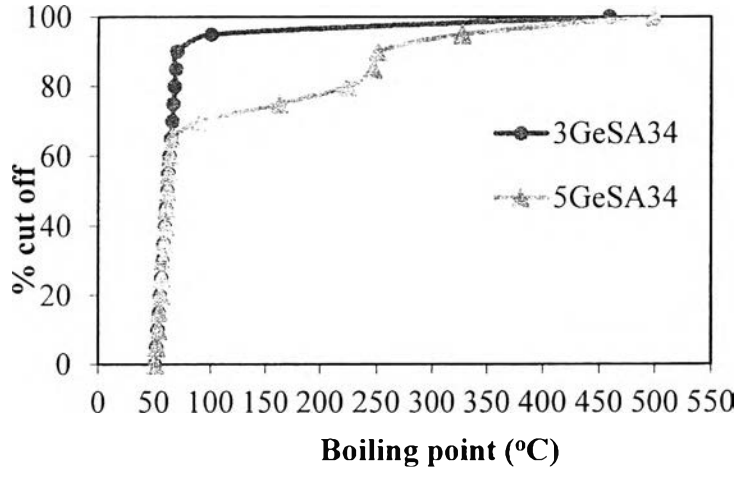


Table E2 True boiling point curves of oil from using gallium oxide-doped SAPO-34 as a catalyst

%OFF	Boiling point (°C)	
	3GaSA34	5GaSA34
0	50.9	49.6
5	52.0	50.9
10	53.1	52.0
15	54.1	53.1
20	55.2	54.1
25	56.3	55.2
30	57.4	56.3
35	58.4	57.4
40	59.5	58.4
45	60.6	59.5
50	61.7	60.6
55	62.7	61.7
60	63.8	62.7
65	64.9	63.8
70	65.9	64.9
75	67.0	65.9
80	68.1	67.0
85	73.5	68.1
90	101.5	69.2
95	107.8	71.1
100	173.2	326.5

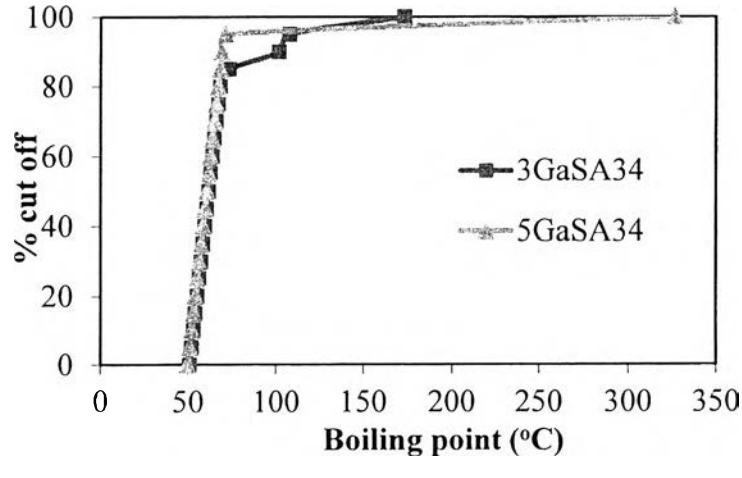


Table E3 True boiling point curves of oil from using tin oxide-doped SAPO-34 as a catalyst

%OFF	Boiling point (°C)	
	3SnSA34	5SnSA34
0	49.4	49.8
5	50.5	51.1
10	51.6	52.4
15	53.1	53.5
20	54.1	54.6
25	55.2	55.6
30	56.3	56.7
35	57.4	57.8
40	58.4	58.9
45	59.5	59.9
50	60.6	61.0
55	61.7	62.1
60	62.7	63.2
65	63.8	64.2
70	64.9	65.3
75	65.9	66.4
80	67.0	67.5
85	68.1	68.5
90	69.2	69.6
95	70.2	74.8
100	303.4	533.6

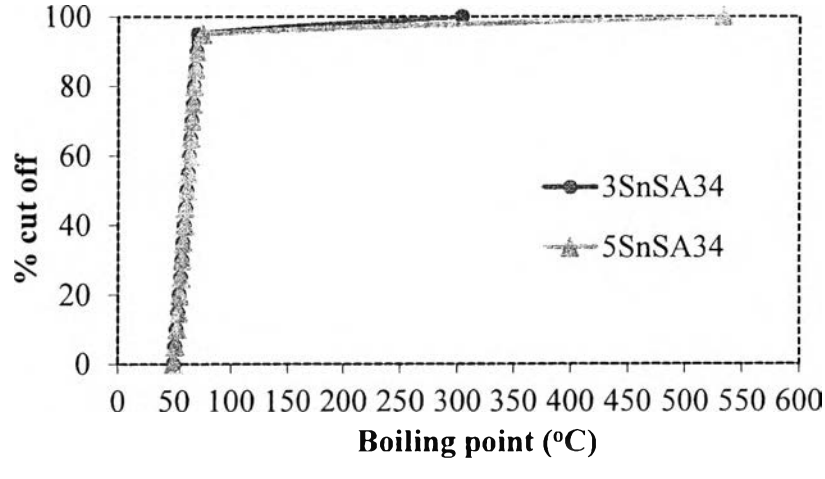


Table E4 True boiling point curves of oil from using antimony oxide-doped SAPO-34 as a catalyst

%OFF	Boiling point (°C)	
	3SbSA34	5SbSA34
0	52.4	51.1
5	55.0	52.8
10	56.5	54.6
15	57.6	55.6
20	58.6	56.7
25	59.7	57.8
30	60.8	58.9
35	61.9	59.9
40	62.9	61.0
45	64.0	62.1
50	65.1	63.2
55	66.2	64.2
60	67.2	65.3
65	68.3	66.4
70	69.4	67.5
75	70.5	68.5
80	71.5	69.6
85	72.6	70.7
90	73.7	71.7
95	74.8	103.1
100	213.5	210.7

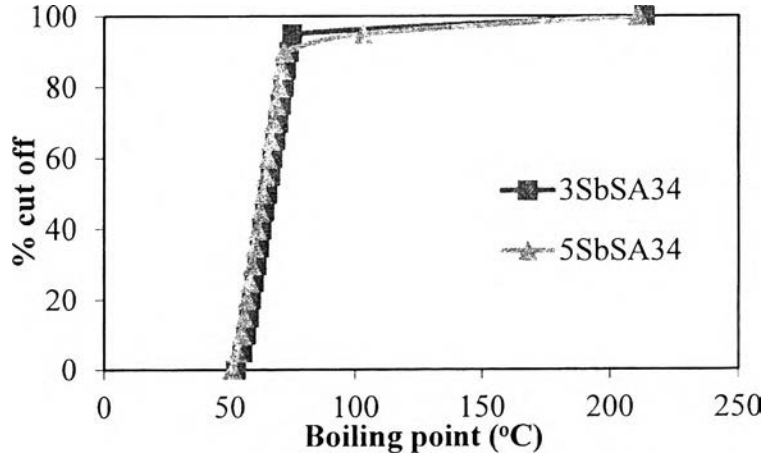
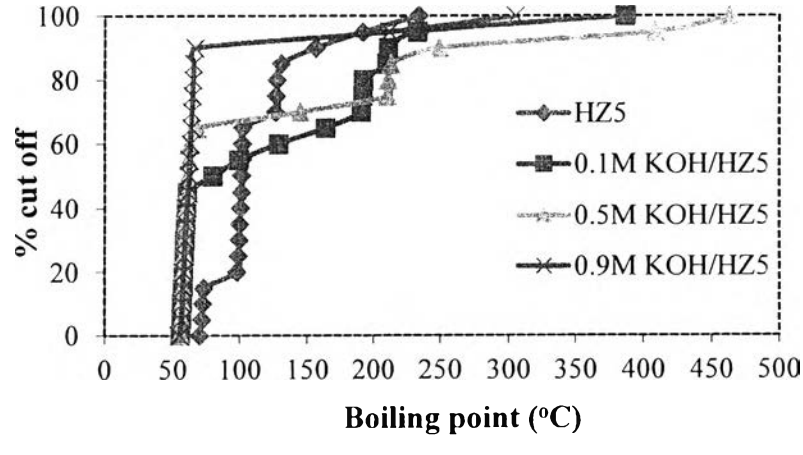


Table E5 True boiling point curves of oil from using KOH-treated HZSM-5 catalysts

%OFF	Boiling point (°C)			
	HZ5	0.1M KOH/HZ5	0.5M KOH/HZ5	0.9M KOH/HZ5
0	70.4	55.7	55.6	55.1
5	71.8	56.6	56.6	56.4
10	72.6	57.1	57.1	57.0
15	73.2	57.7	57.7	57.5
20	98.0	58.2	58.2	58.1
25	99.1	58.7	58.7	58.6
30	99.8	59.2	59.2	59.1
35	100.3	59.8	59.8	59.8
40	100.7	60.3	60.3	60.5
45	101.1	60.8	60.8	61.4
50	101.5	80.1	61.4	62.0
55	101.9	99.6	61.9	62.5
60	102.2	128.8	62.4	63.1
65	102.5	163.7	68.0	63.6
70	126.4	190.9	145.0	64.1
75	127.3	192.0	210.7	64.7
80	128.0	192.4	211.5	65.2
85	130.7	209.9	213.3	65.7
90	156.5	211.1	249.5	66.6
95	192.0	233.1	408.8	211.9
100	234.4	387.0	463.3	304.8



Appendix F Material Safety Data Sheet of SAPO-34

** Section 1 – CHEMICAL PRODUCT AND COMPANY IDENTIFICATION **

MSDS Name:	Zeolite
Catalog Numbers:	CTF-01-50, CTF-02, CTF-03, CTF-03F, CTF-04, CTF-04s, CTF-05
Synonyms:	MOLECULAR SIEVE, ALUMINOSILICATE, SILICO-ALUMINO-PHOSPHATE, SILICA, ALUMINA
Company:	Tianjin Chemist Scientific Ltd.
Address:	1-C-8, No.13 Ziyuan Road, Huayuan Industry Park, Tianjin 300384, China
Telephone:	0086-22-58627636
Fax:	0086-22-58627636

** Section 2 – COMPOSITION, INFORMATION ON INGREDIENTS **

Cas#	Chemical Name	EINECS#
1318-02-1	ZEOLITE	215-283-8

Hazard Symbols: None listed.

Risk Phrases: None listed.

** Section 3 – HAZARDOUS IDENTIFICATION **

EMERGENCY OVERVIEW

Hygroscopic (absorbs moisture from the air).

Potential Health Effects

Eye: May cause eye irritation.

Skin: May cause skin irritation.

Ingestion:	The toxicological properties of this substance have not been fully investigated. May be harmful if swallowed.
Inhalation:	May cause respiratory tract irritation. The toxicological properties of this substance have not been fully investigated.
Chronic:	Not available.

** Section 4 – FIRST AID MEASURES **

Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin:	Get medical aid. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.
Ingestion:	Get medical aid. Wash mouth out with water.
Inhalation:	Remove from exposure and move to fresh air immediately. If not breathing give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

** Section 5 – FIRE FIGHTING MEASURES **

General Information:	As in any fire, wear a self-contained breathing apparatus in pressure-demand, SHA/NIOSH (approved or equivalent), and full protective gear.
Extinguishing Media:	Use extinguishing media most appropriate for the surrounding fire.

** Section 6 – ACCIDENTAL RELEASE MEASURES **

General Information:	Use proper personal protective equipment as indicated in Section 8
Spills/Leaks:	Vacuum or sweep up material and place into a suitable disposal container.

** Section 7 – HANDLING AND STORAGE **

Handling:	A void breathing dust, vapour mist, or gas. Avoid contact with skin and eyes. Take precautionary measures against static discharges.
Storage:	Store in a cool, dry place. Store in a tightly closed container.

** Section 8 – EXPOSURE CONTROLS, PERSONAL PROTECTION **

Engineering Controls: Use adequate ventilation to keep airborne concentrations low.

Personal Protective Equipment

Eyes:	Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 European Standard EN166.
Clothing:	Wear appropriate protective clothing to prevent skin exposure.
Respirators:	Follow the OSHA respirator regulations found in 29 CFR 1910.134 European Standard EN149. Always use a NIOSH or European Standard EN149 approved respirator when necessary.

** Section 9 – PHYSICAL AND CHEMICAL PROPERTIES **

Physical State:	Powder
Color:	White
Odor:	Odorless or slight odor
pH:	Not available.
Vapor Pressure:	Not available.
Viscosity:	Not available.
Boiling Point:	Not available.
Freezing/Melting Point:	Not available.
Autoignition Temperature:	Not available.
Flash Point:	Not available.

Explosion Limits, lower:	Not available.
Explosion Limits, upper:	Not available.
Decomposition Temperature:	
Solubility in water:	insoluble
Specific Gravity/Density:	
Molecular Formula:	
Molecular Weight:	

** Section 10 – STABILITY AND REACTIVITY **

Chemical Stability:	Not available.
Conditions to Avoid:	Incompatible materials, dust generation, exposure to moist air or water.
Incompatibilities with Other Materials:	Strong acids, strong bases, hydrogen fluoride.
Hazardous Decomposition Products:	Not available.
Hazardous Polymerization:	Has not been reported.

** Section 11 – TOXICOLOGICAL INFORMATION **

RTECS#:	Unlisted.
LD50/LC50:	Not available.
Carcinogenicity:	MOLECULAR SIEVES – Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.

** Section 12 – ECOLOGICAL INFORMATION **

See actual entry in RTECS for complete information.

** Section 13 – DISPOSAL CONSIDERATIONS **

Dispose of in a manner consistent with federal, state, and local regulations.

** Section 14 – TRANSPORT INFORMATION **

IATA: Not regulated as a hazardous material.

IMO: Not regulated as a hazardous material.

RID/ADR: Not regulated as a hazardous material.

DOT: Non-Hazardous for Transport: This substance is considered to be non-hazardous for transport.

** Section 15 – REGULATORY INFORMATION **

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols: Not available.

Risk Phrases:

Safety Phrases: S24/25 Avoid contact with skin and eyes.

WGK (Water Dander/Protection)

No information available.

United Kingdom Occupational Exposure Limits

United Kingdom Maximum Exposure Limits

Canada

None of the chemicals in this product are listed on the DSL/NDSL list.

Not listed on Canada's Ingredient Disclosure List.

Exposure Limits

US FEDERAL

TSCA

Not listed on the TSCA inventory.

It is for research and development use only.

Section 16 – ADDITIONAL INFORMATION **

The information above is believed to be accurate and represent the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no way shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if the company has been advised of the possibility of such damages.

CURRICULUM VITAE

Name: Mr. Peerapong Wongwanichsin

Date of Birth: February 08, 1989

Nationality: Thai

University Education:

2007–2010 Bachelor Degree of Engineering (Chemical Engineering), Faculty of Engineering, Mahidol University, Nakhon Pathom, Thailand

Work Experience:

2010	Position:	Internship Student
	Company name:	Star Petroleum Refining Company Limited (SPRC), Rayong, Thailand

Proceeding:

1 Wongwanichsin P., and Jitkarnka, S. (2013, April 23) KOH-Treated HZSM-5 as Catalysts for Dehydration of Bio-ethanol to Light Olefins. Proceedings of The 4th Research Symposium on Petrochemical and Materials Technology and The 19th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.

Presentation:

1. Wongwanichsin, P., and Jitkarnka, S. (2013, June 18-20) Tin Oxide-Doped SAPO-34 as a Catalyst for Dehydration of Bio-Ethanol to Light Olefins. Poster Presentation of The 17th Annual Green Chemistry & Engineering Conference (ACS Meeting), Washington DC, USA.