REFERENCES

1. Department of Business Economics. Available from: http://www.thailand.com/exports/html/industry_iopetrochem.htm[**2004**, Jan 25]
2. Office of Industrial Economics. Available from: http://www.oie.go.th/industry_stat/252010.html[**2003**, Nov 28]
3. Evans, P. J. "Industry and the Environment in Asia", *TDRI Quarterly Review*, **1998**, *13*, 19-27.
4. Bishop, P. L. Pollution Prevention: Fundamentals and Practice. New York: McGraw Hill, **2000**.
5. Szostak, R. Molecular Sieve: Principles of Synthesis and Identification. NewYork: Van Nostrand Reinhold, **1989**.
6. Marcily, C. "Present Status and Future Trends in Catalysis for Refining and Petrochemicals", *J. Catal.*, **2003**, *216*, 47-62.
7. Sheldon, R. A. "Homogeneous catalysts to solid catalysts", *Current Opinion in Solid State & Materials Science*, **1996**, *1*, 101-106.
8. Cynthia, T. -W.; Chang, C. D. "Isomorphous Substitution in Zeolite Frameworks. 1. Acidity of Surface Hydroxyls in [B]-, [Fe]-, [Ga]-, and [Al]-ZSM-5", *J. Phys. Chem.*, **1985**, *89*, 1569-1571.
9. Kresnawahjuesa, O.; Kuhl, G. H.; Gorte, R. J.; Quierini, C. A. "An Examination of Bronsted Acid Sites in H-[Fe]ZSM-5 for Olefin Oligomerization and Adsorption", *J. Catal.*, **2002**, *210*, 106-115.

10. Inui, T.; Miyamoto, A.; Matsuda, H.; Nagata, H.; Makino, Y.; Fukuda, K.; Okazumi, F. "New Aspects in Catalytic Performance of Novel Metallosilicates Having the Pentasil Pore-Opening Structure", *Studies Surface Science Catal.*, **1986**, *28*, 856.

11. Zhao, D.; Feng, J.; Huo, Q.; Melosh, N.; Fredrickson, G. H.; Chmelka, B. F.; Stucky, G. D. "Triblock Copolymer Syntheses of Mesoporous Silica with Periodic 50 to 300 Angstrom Pores", *Science*, **1998**, *279*, 548-552.

12. Zhao, D.; Huo, Q.; Feng, J.; Chmelka, B. F.; Stucky, G. D. "Nonionic Triblock and Star Diblock Copolymer and Oligomeric Surfactant Syntheses of Highly Ordered, Hydrothermally Stable, Mesoporous Silica Structures", *J. Am. Chem. Soc.*, **1998**, *120*, 6024-6036.

13. Yue, Y.; Gedeon, A.; Bonardet, J. -L.; Melosh, N.; D'Espinose, J. -B.; Fraissard, J. "Direct Synthesis of AlSBA Mesoporous Molcular Sieves: Characterization and Catalytic Activities", *Chem. Commun.*, 1999, 1967-1968.

14. Luan, Z.; Hartmann, M.; Zhao, D.; Zhou, W.; Kevan, L. "Alumination and Ion Exchange of Mesoporous SBA-15 Molecular Sieves", *Chem. Mater.*, **1999**, *11*, 1621-1627.

15. Newalkar, B. L.; Olanrewaju, J.; Komarneni, S. "Direct Synthesis of Titanium-Substituted Mesoporous SBA-15 Molecular Sieve under Microwave-Hydrothermal Conditions", *Chem. Mater.*, **2001**, *13*, 552-557.

16. Newalkar, B. L.; Olanrewaju, J.; Komarneni, S. "Microwave-Hydrothermal Synthesis and Characterization of Zirconium Substituted SBA-15 Mesoporous Silica", *J. Phys. Chem. B*, **2001**, *105*, 8356-8360.

17. Penders, M. H. G. M.; Nilsson, S.; Piculell, L.; Lindman, B. "Clouding and Diffusion of a Poly(ethylene oxide)-Poly(propylene oxide)-Poly(ethylene oxdie) Block Copolymer in Agarose Gels and Solutions", *J. Phys. Chem.*, **1994**, *98*, 5508-5513.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

18. Bagshaw, S. A.; Prouzet, E.; Pinnavaia, T. J. "Templating of Mesoporous Molecular-Sieves by Nonionic Polyethylene Oxide Surfactants", *Science,* **1995**, *269,* 1242-1244.

19. Attard, G. S.; Glyde, J. C.; Goltner, C. G. "Liquid-Crystalline Phases as Templates for the Synthesis of Mesoporous Silica", *Nature,* **1995**, *378*, 366-368.

20. Templin, M.; Franck, A.; Chesne, A. D.; Leist, H.; Zgang, Y.; Ulrich, R.; Schadler, U.; Wiesner, U. "Organically Modified Aluminosilicate Mesostructure from Block Copolymer Phase", *Science,* **1997**, *278*, 1795-1798.

21. Voegtlin, A. C.; Ruch, F.; Guth, J. L.; Patarin, J.; Huve, L. "F-Mediated Synthesis of Mesoporous Silica with Ionic- and Non-Ionic Surfactants. A New Templating Pathway", *Microporous Mater.,* 1997, *9*, 95-105.

22. Schmidt-Winkel, P.; Glinka, C. J.; Stucky, G. D. "Microemulsion Templates for Mesoporous Silica", *Langmuir,* **2000**, *16*, 356-361.

23. Wang, Y.; Noguchi, M.; Takahashi, Y.; Ohtsuka, Y. "Synthesis of SBA-15 with Different Pore Sizes and the Utilization as Supports of High Loading of Cobalt Catalysts", *Catal. Today,* **2001**, *68*, 3-9.

24. Galarneau, A.; Cambon, H.; Renzo, F. D.; Fajula, F. "Ture Microporosity and Surface Area of Mesoporous SBA-15 Silicas as a Function of Synthesis Temperature", *Langmuir,* **2001**, *17*, 8328-8335.

25. Fan, J.; Yu, C.; Wang, L.; Tu, B.; Zhao, D.; Sakamoto, Y.; Terasaki, O. "Mesotunnels on the Silica Wall of Ordered SBA-15 to Generate Three-Dimensional Large - Pore Mesoporous Networks", *J. Am. Chem. Soc.,* **2001**, *123*, 12113-12114.

26. Ryoo, R.; Ko, C. H. "Block-Copolymer-Templated Ordered Mesoporous Silica: Array of Uniform Mesopores or Mesopore-Micropore Network?", *J. Phys. Chem. B*, **200**, *104*, 11465-11471.

27. Newalkar, B. L.; Komarneni, S.; "Control over Microporosity of Ordered Microporous-Mesoporous Silica SBA-15 Framework under Microwave-Hydrothermal Conditions: Effect of Salt Addition", *Chem. Mater.,* **2001**, *13*, 4573-4579.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

28. On, D. T.; Giscard, D. D.; Danumah, C.; Kaliaguine, S. "Perspectives in Catalytic Applications of Mesostrucutred Materials", *Appli. Catal. A Gen.*, **2003**, *253*, 545-602.

29. Zhang, W. -H.; Lu, J.; Han, B.; Li, M.; Xiu, J.; Ying, P.; Li, C. "Direct Synthesis and Characterization of Titatium-Substituted Mesoporous Molecular Sieve SBA-15", *Chem. Mater*, **2002**, *14*, 3413-3421.

30. Han, Y.; Xiao, F.; Wu, S.; Sun, Y.; Meng, X.; Li, D.; Lin, S. "A Novel Method for Incorporation of Heteroatoms into the Framework of Ordered Mesoporous Silica Materials Synthesized in Strong Acidic Media", *J. Phys. Chem. B*, **2001**, *105*, 7963-7966.

31. Ratnasamy, P.; Kumar, R. "Ferrisilicate Analogs of Zeolites", *Catal. Today*, **1991**, *9*, 328-416.

32. Han, Y.; Meng, X.; Guan, H.; Yu, Y.; Zhao, L.; Xu, X.; Yang, X.; Wu, S.; Li, N.; Xiao, F.-S. "Stable Iron-Incorporated Mesoporous Silica Materials (MFS-9) Prepared in Strong Acidic Media", *Micro. Meso. Mater.*, **2003**, *57*, 191-198.

33. Inui, T.; Nagata, H.; Yamase, O.; Matuda, H.; Kuroda, T.; Yoshigawa, M.; Takeguchi, T.; Miyamoto, A. "Methanol to Hydrocarbon Conversion on Fe-Silicates Prepared from Fe2+ and Fe3+ Sources", *Appl. Catal.*, **1986**, *24*, 257.

34. Bruckner, A.; Lohse, U.; Mehner, H. "The Incorporation of Iron Ions in AlPO4-5 Molecular Sieves after Microwave Synthesis Studied by EPR and Mössbauer spectroscopy", *Micro. Meso. Mater.*, **1998**, *20*, 207-215.

35. Trustees of Dartmouth College. Available from: http://www.dartmouth.edu/~genchem/0102/sring/6winn/catalysis.html[**2003**, Mar 11]

36. Leach, B. E. Applied Industrial Catalysis Volumn 1. London: Academic press, **1983**.

37. Zones, S. I.; Davis, M. E. "Zeolite Materials : Recent Discoveries and Future Prospects", *Current Opinion in Solid State & Materials Science*, **1996**, *1*, 107-117.

38. Morbidelli, M.; Gavriilidis, A.; Varma, A. Catalyst Design : Opitmal Distribution of Catalyst in Pellets, Reactors, and Membranes. London: Cambridge University press, **2001**.

39. Breck, D. W. Zeolite Molecular Sieves: Structure, Chemistry, and Use. Florida: Robert E. Krieger Publishing Company, **1973**.

40. Geoscience Department. Available from: http://www.geo.wvu.edu/~wilson/geol1/lec15/lec154.htm[2003, Nov 28]

41. Swaddle, T. W.; Salerno, J.; Tregloan, P. A. "Aqueous Aluminates, Silicates, and Aluminosilicates", *Chem. Soc. Rev.,* **1995**, 319-325.

42. Kinrade, S. D.; Swaddle, T. W. "Silicon-29 NMR Studies of Aqueous Silicate Solutions. I. Chemical Shifts and Equilibria", *Inorg. Chem.,* **1988**, *27*, 4253-4259.

43. Dyer, A. An Introduction to Zeolite Molecular Sieves. NewYork: John Wiley & Sons., **1988**.

44. Scott, J. Zeolite Technology and Applications: Recent Advances. New Jersey: Noyes Data Corporation, **1980**.

45. Corma, A. "Inorganic Solid Acids and Their Use in Acid-Catalyzed Hydrocarbon Reactions", *Chem. Rev.* **1995**, *95*, 559-614.

46. Moden, B.; Costa, P. D.; Fonfe, B.; Lee, D. K.; Iglesia, E. "Mechanism of Steady-State Catalytic NO Decomposition Reaction on Cu-ZSM-5", *J. Cat.,* **2002**, *209*, 75-86.

47. Hedoire, C. E.; Louis, C.; Davidson, A.; Breysee, M.; Mauge, F.; Vrinat, M. "Support Effect in Hydrotreating Catalysts: Hydrogenation Properties of Molydenum Sulfide Supported on Beta-Zeolites of Various Acidities", *J. Cat.,* **2003**, *2*, 433-441.

48. Davidson, A. "Modifying the Walls of Mesoporous Silicas Prepared by Supramolecular-Templating", *Current Opinion in Colloid & Interface Science,* **2002**, *7*, 92-106.

49. Ryoo, R.; Kim, J. M.; Ko, C. H.; Shin, C. H. "Disordered Molecular Sieve with Branched Mesoporous Channel Network", *J. Phys. Chem.,* **1996**, *100*, 17718-17721.

50. Beck, J. S.; Vartuli, C.; Roth, W. J.; Leonowicz, M. E.; Kresge, C. T.; Schmitt, K. D.; Chu, C. T-W.; Olson, D. H.; Sheppard, E. W.; McCullen, S. B.; Higgins, J. B.; Schlenker, J. L. "A New Family of Mesoporous Molecular Sieves Prepared with Liquid Crystal Templates", *J. Am. Chem. Soc.,* **1992**, *114*, 10834-10843.

51. Pelrine, B. P.; Schmitt, K. D.; Vartuli, J. C. "Production of Olefin Oligomer", *U.S. Patent, 5105051*, **1992**.

52. Corma, A.; Mertinez, A.; Martinez-Soria, V.; Monton, J. B. "Hydrocracking of Vacuum Gasoil on the Novel Mesoporous MCM-41 Aluminosilicates Catalysts", *J. Catal.,* **1995**, *153*, 25-31.

53. Newalkar, B. L.; Choudary, N. V.; Kumar, P.; Komarneni, S.; Bhat, T. S. G. "Exploring the Potential of Mesoporous Silica, SBA-15, as an Adsorbent for Light Hydrocarbon Separation", *Chem. Mater.,* **2002**, *14*, 304-309.

54. Gusev, V. Y.; Feng, X.; Bu, Z.; Haller, G. L.; O'Brien, J. A. "Mechanical Stability of Pure Silica Mesoporous MCM-41 by Nitrogen Adsorption and Small-Angle X-ray Diffraction Measurements", *J. Phys. Chem.,* **1996**, *100*, 1985-1988.

55. Tatsumi, T.; Koyano, K. A.; Tanaka, Y.; Nakata, S. "Mechanical Stability of Mesoporous Materials, MCM-48 and MCM-41", *J. Porous. Mater.,* **1999**, *6*, 13-17.

56. Mokaya, R. "Improving the Stability of Mesoporous MCM-41 silica via Thicker More Highly Condensed Pore Walls", *J. Phys. Chem. B.,* **1999**, *103*, 10204-10208.

57. Kim, J. M.; Kwak, J. H.; Jun, S.; Ryoo, R. "Ion Exchange and Thermal Stability of MCM-41", *J. Phys. Chem.,* **1995**, *99*, 16742-16747.

58. Edler, K. J.; White, J. W. "Further Improvements in the Long-Range Order of MCM-41 Materials", *Chem. Mater.,* **1997**, *9*, 1226-1233.

59. Sayari, A.; Liu, P.; Kruk, M.; Jaroniec, M. "Characterization of Large-Pore MCM-41 Molecular Sieves Obtained via Hydrothermal Restructuring", *Chem. Mater.*, **1997**, *9*, 2499-2506.

60. Chen, L.; Horiuchi, T.; Mori, T.; Maeda, K. "Postsynthesis Hydrothermal Restructuring of M41S Mesoporous Molecular Sieves in Water", *J. Phys. Chem. B*, **1999**, *103*, 1216-1222.

61. Koyano, K. A.; Tatsumi, T.; Tanaka, Y.; Nakata, S. "Stabilization of Mesoporous Molecular Sieves by Trimethylsilylation", *J. Phys. Chem. B*, **1997**, *101*, 9436-9440.

62. Zhao, X. S.; Lu, G. Q. "Modification of MCM-41 by Surface Silylation with Trimethylchlorosilane and Adsorption Study", *J. Phys. Chem. B*, **1998**, *102*, 1556-1561.

63. Ryoo, R.; Jun, S. "Improvement of Hydrothermal Stability of MCM-41 Using salt Effects during the Crystallization Process", *J. Phys. Chem. B*, **1997**, *101*, 317-320.

64. He, N.; Lu, Z.; Yuan, C.; Hong, J.; Wang, C.; Bao, S.; Xu, Q. "Effects of Trivalent Elecments on the Thermal and Hydrothermal Stability of MCM-41 Mesoporous Molecular Materials", *Supramolecular Science*, **1998**, *5*, 553.

65. Cassiers, K.; Linssen, T.; Mathieu, M.; Benjalloun, M.; Schrijnemakers, K.; Van Der Voort, P.; Cool, P.; Vansant, E. F. "A Datailed Study of Thermal, Hydrothermal, and Mechanical Stabilities of a Wide Range of Surfactant Assembled Mesoporous Silicas", *Chem. Mater.*, **2002**, *14*, 2317-2324.

66. Hartmann, M.; Vinu, A. "Mechanical Stability and Porosity Analysis of Large-Pore SBA-15 Mesoporous Molecular Sieves by Mercury Porosimetry and Organics Adsorption", *Langmuir*, **2002**, *18*, 8010-8016.

67. Wu, P.; Tatsumi, T. "Postsynthesis, Characterization, and Catalytic Properties in Alkene Epoxidation of Hydrothermally Stable Mesoporous Ti-SBA-15", *Chem. Mater.*, **2002**, *14*, 1657-1664.

68. Bennadja, Y.; Beaunier, P.; Margolese, D.; Davidson, A. "Fine Tuning of the Interaction between Pluronic Surfactants and Silica Walls in SBA-15 Nanostructured Materials", *Micro. Meso. Mater.*, **2001**, *44-45*, 147-152.

69. Khushalani, D.; Kuperman, A.; Coombs, N.; Ozin, G. A. "Mixed Surfactant Assemblies in the Synthesis of Mesoporous Silicas", *Chem. Mater.*, **1996**, *8*, 2188-2193.

70. Lawrence, M. J. "Surfactant Systems: Their Use in Drug Delivery", *Chem. Soc. Rev.*, **1994**, 417-424.

71. Zhao, X. S.; Lu, G. Q.; Millar, G. J. "Advances in Mesoporous Molecular Sieve MCM-41", *Ind. Eng. Chem. Res.*, **1996**, *35*, 2075-2090.

72. Kabanov, A. V.; Nazarova, I. R.; Astafleva, I. V.; Batrakova, E. V.; Alakhov, V. Y.; Yaroslavov, A. A.; Kabanov, V. A. "Micelle Formation and Solubilization of Fluoresent Probes in Poly(oxyethylene-b-oxypropylene-b-oxyethylene) Solution", *Macromolecules*, **1995**, *28*, 2303-2314.

73. Soler-Illia, G. J.; Sanchez, C.; Lebeau, B.; Patarin, J. "Chemical Strategies to Design Textured Materials: from Microporous and Mesoporous Oxides to Nanonetworks and Hierarchical Structures", *Chem. Rev.*, **2002**, *102*, 4093-4138.

74. Hou, Q.; Margolese, D. I.; Ciesla, U.; Demuth, D. G.; Feng, P.; Gier, T. E.; Sieger, P.; Firouzi, A.; Chmelka, B. F.; Schuth, F.; Stucky, G. D. "Organization of Organic Molecules with Inorganic Molecular Species into Nanocomposite Biphase Arrays:, *Chem. Mater.*, **1994**, *6*, 1176-1191.

75. Alexandridis, P.; Holzwarth, J. F.; Hatton, T. A. "Micellization of Poly(ethylene oxide)-Poly(propylene oxide)-Poly(ethylene oxide) Triblock Copolymers in Aqueous Solution: Thermodynamics of Copolymer Association", *Macromolecules*, **1994**, *27*, 2414-2425.

76. Tanev, P.; Pinnavaia, T. J. "A Neutral Templating Route to Mesoporous Molecular Sieves", *Science*, **1995**, *267*, 865-867.

77. Glodfarb, D.; Bernardo, M.; Strohmaier, K. G.; Vaughan, D. E. W.; Thomann, H. "Characterization of Iron in Zeolites by X-band and Q-band ESR, Pulse ESR, and UV-Visible Spectroscopies", *J. Am. Chem. Soc.*, **1994**, *116*, 6344-6353.

78. Bordiga, S.; Buzzoni, R.; Geobaldo, F.; Lamberti, C.; Giamello, E.; Zecehina, A.; Leofanti, G.; Petrini, G.; Tòzzola, G.; Vlaic, G. "Structure and Reactivity of Framework and Extraframework Iron in Fe-Silicate as Investigated by Spectroscopic and Physicochemical Methods", *J. Cat.*, **1996**, *158*, 468-501.

79. Shiralkar, V. P.; Joshi, P. N.; Awate, S. V. "Partial Isomorphous Substitution of Fe3+ in the LTL Framework", *J. Phys. Chem.*, **1993**, *97*, 9749-9753.

80. Xu, Q. –H.; He, N. –Y.; Bao, S. –L. "Synthesis and Characterization of FeSiMCM-41 and LaSiMCM-41" *Studies Surface Science Catal.*, **1997**, *105*, 85-92.

81. Bruckner, A.; Lohse, U.; Mehner, H. " The Incorporation of Iron in AlPO4-5 Molecular Sieves after Microwave Synthesis Studied by EPR and Mossbauer Spectroscopy", *Micro. Meso. Mater.*, **1998**, *20*, 207-215.

82. Selvam, P.; Dapurkar, S.; Badamali, S.; Murugasan, M.; Kuwano, H. "Coexistence of Paramagnetic and Superparamagnetic Fe(III) in Mesoporous MCM-41 Silicates", *Catal. Today*, **2001**, *68*, 69-74.

83. Wang, Y.; Zhang, Q.; Shishido, T.; Takehira, K. "Characterizations of Iron-Containing MCM-41 and Its Catalytic Properties in Epoxidation of Styrene with Hydrogen Peroxide", *J. Cat.*, **2002**, *209*, 186-196.

84. Gale, J. D.; Shah, R.; Payne, M. C.; Stich, I.; Terakura, K. "Methanol in Microporous Materials from First Principles", *Catal. Today*, **1999**, *50*, 525-532.

85. Park, T. Y.; Fremont, G. F. "Kinetic Modeling of the Methanol to Olefins Process: 1. Model Formation", *Ind. Eng. Chem. Res.*, **2001**, *40*, 4172-4186.

86. Hirao, K.; Tajima, N.; Tsuneda, T.; Toyama, F. "A New Mechanism for the First Carbon-Carbon Bond Formation in the MTG Process: a Theoretical Study", *J. Am. Chem. Soc.*, **1998**, *120*, 8222-8229.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

87. Stocker, M. "Review: Methanol-to-Hydrocarbons: Catalytic Materials and Their Behavior", *Micro. Meso. Mater.*, **1999**, *29*, 3-48.

88. Dahl, I. M.; Kolboe, S. "On the Reaction Mechanism for Hydrocarbon Formation from Methanol over SAPO-34: 1. Isotopic Labeling Studies of the Co-Reaction of Ethane and Methanol" *J. Cat.*, **1994**, *149*, 458-464.

89. Dahl, I. M.; Kolboe, S. "On the Reaction Mechanism for Hydrocarbon Formation from Methanol over SAPO-34: 2. Isotopic Labeling Studies of the Co-Reaction of Propene and Methanol" *J. Cat.*, **1996**, *161*, 304-309.

90. Hunger, M.; Seiler, M.; Schenk, U. "Conversion of Methanol to Hydrocarbons on Zeolite HZSM-5 Investigated by *in situ* MAS NMR Spectroscopy under Flow Conditions and On-line Gas Chromatography", *Catal. Lett.*, **1999**, *62*, 139-145.

91. Hunger, M.; Seiler, M.; Buchholz, A. "*In situ* MAS NMR Spectroscopy Investigation of the Conversion of Methanol to Olefins on Silicoaluminophosphates SAPO-34 and SAPO-18 under Continuous Flow Conditions", *Catal. Lett.*, **2001**, *74*, 61-68.

92. Derouane, E. G. "New Aspects of Molecular Shape-Selectivity: Catalysis by Zeolite ZSM-5", *Studies Surface Science Catal.*, **1980**, *5*, 5-18.

93. Schulz, H.; Siwei, Z.; Baumgatner, W. "Coke Formation Reaction during Methanol Conversion on Zeolite Catalysts", *Studies Surface Science Catal.*, **1987**, *34*, 479-490.

94. Li, Q.; Mihailova, B.; Creaser, D.; Sterte, J. "Aging Effects on the Nucleation and Crystallization Kinetics of Colloidal TPA-Silicate-1", *Micro. Meso. Mater.*, **2001**, *43*, 51-59.

95. Koroglu, H. J.; Sarioglan, A.; Tather, M.; Erdem-Senatala, A.; Savasci, O. T. "Effects of Low-Temperature Gel Aging on the Synthesis of Zeolite Y at Different Alkalinities", *J. Crystal Growth*, **2002**, *241*, 481-488.

96. Cheng, C. –F.; Park, D. H.; Klinowski, J. "Optimal Parameters for the Synthesis of the Mesoporous Molecular Sieve [Si]-MCM-41", *J. Chem. Soc., Faraday Trans.*, **1997**, *93*, 193-197.

97. Lin, H. –P.; Kuo, C. –L.; Wan, B. –Z.; Mou, C. –Y. "Optimum Synthesis of Mesoporous Silica Materials from Acidic Condition", *J. Chin. Chem. Soc.*, **2002**, *49*, 899-906.

98. Pasqua, L.; Testa, F.; Aiello, R.; Renzo, F. D.; Fajula, F. "Influence of pH and Nature of the Anion on the Synthesis of Pure and Iron-Containing Mesoporous Silica", *Micro. Meso. Mater.*, **2001**, *44-45*, 111-117.

99. Waitayawan, J. The Effect of Aluminum on Effeciency of Mordenite Catalyst for Conversion of Methanol to Olefins. (Master's Thesis, Petrochemistry and Polymer Science, Faculty of Science, Graduate School, Chulalongkorn University, Thailand, 2002).

100. Sangvaraporn, I. Iron-Containing MFI Catalysts for Conversion of Methanol to Olefins. (Master's Thesis, Department of Chemistry, Faculty of Science, Graduate School, Chulalongkorn University, Thailand, 2003).

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APPENDICES

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Appendices

A-1 Calculation for vapor pressure of methanol

Antoine's equation

$$\text{In}\,(P \times (Vp/P_c)) \;=\; (1\text{-}X)^{-1}[(VpA)X + (VpB)X^{1.5} + (VpC)X^{3} + (VpC)X^{6}] \qquad \text{(A-1)}$$

Where P = Total pressure

Vp = Vapor pressure

P_c = Critical pressure

$X = 1 - (T/T_c)$; T_c = critical temperature, T = trial temperature (K)

VpA, VpB, VpC, VpD = constants

Example: Determination of vapor pressure of methanol at 30°C

For methanol; T_c = 512.6 K, P_c = 80.9 atm P = 1 atm

VpA = -8.54796, VpB = 0.76982, VpC = -3.10850,

VpD = 1.54481, T = 30°C = 301.15 K

$X = 1 - (303.15/512.6) = 0.40860$

$$\text{In}\,(1\times(Vp/80.9)) = (1\text{-}0.40860)^{-1}[(-8.54796)(0.40860) + (0.76982)(0.40860)^{1.5} + (-3.10850)(0.40860)^{3} + (1.54481)(0.40860)^{6}]$$

$\text{In}\,(Vp/80.9) = -5.9123$

$Vp/80.9 = \exp(-5.9123) = 2.706 \times 10^{-3}$

$Vp = 0.2189$ atm

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A-2 Calculation for Feed Flow Rate

The amount of catalyst used = 0.25 g

The tubular reactor (inside diameter = 0.54 cm)

The average height of catalyst bed = 2.0 cm, so that,

Volume of the catalyst bed $= \pi r^2 h = (22/7) \times (0.27)^2 \times 2.0$

$= 0.4582$ cm^3-cat.

Use Gas Hourly Space Velocity (GHSV) = 2000 h^{-1}

$$GHSV = \frac{\text{Volumetric flow rate}}{\text{Volume of bed}} \quad \text{at STP condition}$$

Volumetric flow rate $= 2000 \times 0.4582 = 916.4\ cm^3/h$

$= 916.4/60 = 15.30\ cm^3/min$

At room temperature

Volumetric flow rate $= 15.30\ \frac{(273.15 + T)}{273.15}$,

Where T = measured temperature of methanol saturator (°C)

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A-3 Calculation of GC Peak Area to Concentration

$$C_x = \frac{A_x \times C_{std} \times V_{std}}{A_{std} \times V_x} \qquad \text{(A-2)}$$

$$\%\ \text{selectivity} = \frac{C_x \times 100}{C_{total}} \qquad \text{(A-3)}$$

When C_{std} = Concentration of the component of interest in the standard mixture, % mol

C_x = Concentration of the component in the sample, % mol.

C_{total} = Concentration of the total component in the sample, % mol.

A_{std} = Peak area of the component in standard mixture, au.

A_x = Peak area of the component in the sample, au.

V_{std} = injected volume of the standard mixture, μl.

V_x = injected volume of the sample, μl.

If data of proylene, $A_{propylene}$ = 105380; A_{std} = 190640; C_{std} = 15.0 % mol;

V_{std} = 2.0 μl; $V_{propylene}$ = 10 μl, C_{total} = 3.097 % mol

$$C_{propylene} = \frac{105380 \times 15.0 \times 2.0}{190640 \times 10}$$

$$= 1.66\%\ \text{molar}$$

$$\%\ \text{selectivity to propylene} = \frac{1.66 \times 100}{3.097}$$

$$= 53.54$$

A-4 Calculation for Initial Weight of Feed Methanol

$$PV = nRT \tag{A-4}$$

When P = partial pressure of methanol, atm

V = volumn of gas, L

n = mole of methanol, mol

R = constant = $0.082 \text{ atm} \bullet \text{L} \bullet \text{mol}^{-1} \bullet \text{K}^{-1}$

T = temperature of methanol, K

If P = 0.2189 atm, V = 0.5381 L, T = 30°C = 303.15 K

$$n = \frac{PV}{RT}$$

$$= \frac{0.2189 \times 0.5381}{0.082 \times 303.15}$$

$$= 0.004739 \text{ mol} = 0.1579 \text{ g}$$

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A-5 Calculation for Yield of Gas Product and Liquid Product

$$\%\text{ Yield of liquid product} = \frac{\text{wt. liquid product}}{\text{wt. MeOH}} \times \%\text{conversion} \qquad \text{(A-5)}$$

$$\%\text{ Yield of gas product} = \frac{\text{wt. gas product}}{\text{wt. MeOH}} \times \%\text{conversion} \qquad \text{(A-6)}$$

When wt. gas product = wt.MeOH – wt. liquid product – wt. coke

If wt. MeOH = 0.1517 g, wt. liquid product = 0.1199 g, wt. coke = 0.0022 g

$$\%\text{ Yield of liquid product} = \frac{0.1199}{0.1517} \times 99$$

$$= 78.24$$

$$\%\text{ Yield of gas product} = \frac{0.1517 - 0.1199 - 0.0022}{0.1517} \times 99$$

$$= 19.32$$

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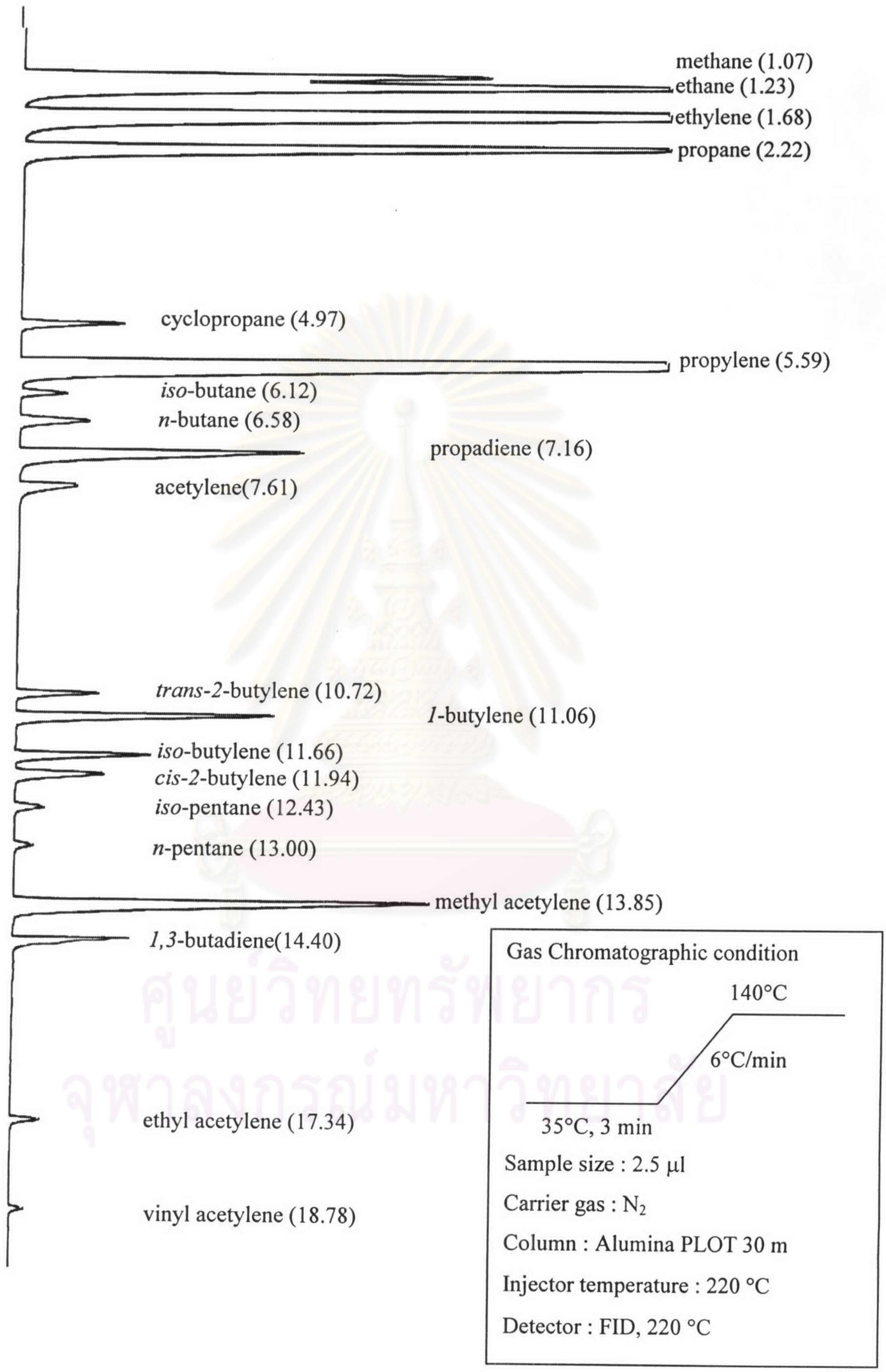

Figure A-1 Gas chromatogram of standard mixture C_4 gas.

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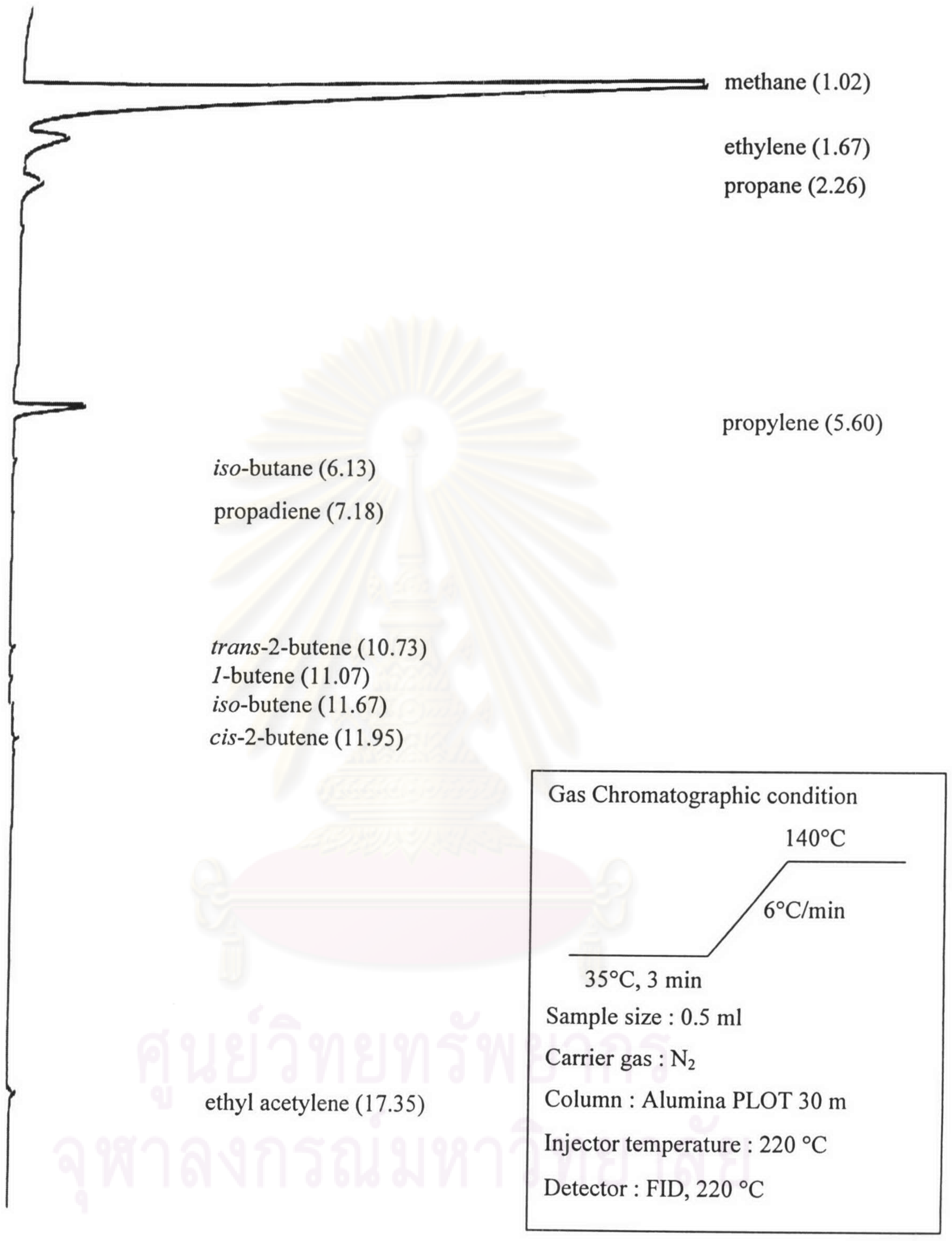

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Figure A-2 Gas chromatogram of gas product from methanol conversion reaction on Fe-SBA-15 (Si/Fe ratio = 90) at 400°C (Condition: 0.25 g of catalyst, feed at GHSV of 2000 h^{-1}, T_{MeOH} = 35°C, time on stream 30 min.).

VITAE

Mr. Kullatat Suwatpipat was born on February 27, 1980 in Bangkok, Thailand. He received a Bachelor Degree of Science in Chemistry from Chulalongkorn University in 2001. Since then, he has been a graduate student studying Inorganic Chemistry in Faculty of Science, Chulalongkorn University. During his graduate studies towards his Master's degree, he also received a teaching assistant scholarship by the Faculty of Science in 2002 and a research grant from the Graduate School, Chulalongkorn University. His permanent address is 160/38 Phetkasam Road Phasricharean District Bangkok 10160.

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