

## REFERENCES

- “Glycerol.” Bookrags, World of Chemistry. Thomson Corporation. 20 Apr. 2008 <<http://www.bookrags.com/research/glycerol-woc/>>
- “Glycerol.” Wikipedia, the Free Encyclopedia. Wikimedia Foundation, Inc. 20 Apr. 2008 <<http://en.wikipedia.org/wiki/Glycerol>>
- A: General, 212(1–2), 17–60.
- Agila, G., Gracia, F., Cortes, J., Araya, P. (2008). Effect of copper species and the presence of reaction products on the activity of methane oxidation on supported CuO catalysts. Applied Catalysis B: Environmental, 77(3–4), 325–338.
- Alhanash, A., Kozhevnikov, E.F., and Kozhevnikov, I.V. (2008). Hydrogenolysis of glycerol to propanediol over Ru: Polyoxometalate bifunctional catalyst. Catalysis Letters, 120(3-4), 307–311.
- Arena, B.J. (1992). Deactivation of ruthenium catalysts in continuous glucose hydrogenation. Applied Catalysis A: General, 87(2), 219–229.
- Bartholomew, C.H. (2001). Mechanisms of catalyst deactivation. Applied Catalysis
- Behr, A., Eilting, J., Irawadi, K., Leschinski, J., and Lindner, F. (2008). Improved utilisation of renewable resources: New important derivatives of glycerol. Green Chemistry, 10(1), 13–30.
- Besson, M., and Gallezot, P. (2003). Deactivation of metal catalysts in liquid phase organic reactions. Catalysis Today, 81(4), 547–559.
- Besson, M., Gallezot, P., Pigamo, A., and Reifsnyder, S. (2003). Development of an improved continuous hydrogenation process for the production of 1,3-propanediol using titania supported ruthenium catalysts. Applied Catalysis A: General, 250(1), 117–124.
- Cant, N.W., Tonner, S.P., Trimm, D.L., and Wainwright, M.S. (1985). Isotopic labeling studies of the mechanism of dehydrogenation of methanol to methyl formate over copper-based catalysts. Journal of Catalysis, 91(2), 197-207.
- Casale, B. and Gomez, A.M. (1993). Method of hydrogenating glycerol. United State Patent, 5,214,219.

- Casale, B. and Gomez, A.M. (1994). Catalytic method of hydrogenating glycerol. United State patent, 5,276,181.
- Chaminand, J., Djakovitch, L., Gallezot, P., Marion, P., Pinel C., and Rosier, C. (2004). Glycerol hydrogenolysis on heterogeneous catalyst. Green Chemistry, 6, 359–361.
- Che, T.M. and Westfield, N.J. (1987). Production of propanediols. United State Patent, 4,642,394.
- Chien, C., Shi, J., and Huang, T. (1997). Effect of oxygen vacancy on CO-NO-O<sub>2</sub> reaction over yttria-stabilized zirconia-supported copper oxide catalyst. Industrial & engineering chemistry research, 36(5), 1544–1551.
- Dasari, M.A., Kiatsimkul, P., Sutterlin, W.R., and Suppes, G.J. (2005). Low-pressure hydrogenolysis of glycerol to propylene glycol. Applied Catalysis A: General, 281(1-2), 225–231.
- Detroy, R.W. and Julian, G.St. (1982). Biomass conversion: Fermentation chemicals and fuels. Microbiology, 10(3), 203–228.
- Drent, E. and Jager, W.W. (2000). Hydrogenolysis of glycerol. United State Patent, 6,080,898.
- El-Shobaky, G.A., Fagal, G.A., and Mokhtar, M. (1997). Effect of ZnO on surface and catalytic properties of CuO/Al<sub>2</sub>O<sub>3</sub> system. Applied Catalysis A: General, 155(2), 167–178.
- Feng, J., Fu, H., Wang, J., Li, R., Chen, H., and Li, X. (2008). Hydrogenolysis of glycerol to glycals over ruthenium catalysts: Effect of support and catalyst reduction temperature. Catalysis Communications, 9(6), 1458-1464.
- Francesco, A., Giuseppe, I., Katia, B., Silvia, B., Giuseppe, B., Lorenzo, S., and Francesco, F. (2008). Solid-state interactions, adsorption sites and functionality of Cu-ZnO/ZrO<sub>2</sub> catalysts in the CO<sub>2</sub> hydrogenation to CH<sub>3</sub>OH. Applied Catalysis A: General, 350(1), 16-23.
- Fujitani T., Saito, M., Kanai, Y., Kakumoto, T., Watanabe, T., Nakamura, J., and Uchijima, T. (1994). The role of metal oxides in promoting a copper catalyst for methanol synthesis. Catalysis Letters, 25, 271–276.

- Haas, T., Neher, A., Arntz, D., Klenk, H., and Girke, W. (1995). Process for the simultaneous production of 1,2- and 1,3-propanediol. United State Patent, 5,426,249.
- Heck, R.M., and Farrauto, R.J. (2001). Automobile exhaust catalysts. Applied Catalysis A: General, 221(1–2), 443–457.
- Huang, T., Lee, K., Yang, H., and Dow, W. (1998). Effect of chromium addition on supported copper catalysts for carbon monoxide oxidation. Applied Catalysis A: General, 174(1–2), 199–206.
- Kenar, J.A. (2007). Glycerol as a platform chemical: Sweet opportunities on the horizon?. Lipid Technology, 19(11), 249–253.
- Kim, S.C. (2002). The catalytic oxidation of aromatic hydrocarbons over supported metal oxide. Journal of Hazardous Materials, 91(1–3), 285–299.
- Kundakovic, L.J. and Flytzani-Stephanopoulos. (1998). Reduction characteristics of copper oxide in cerium and zirconium oxide systems. Applied Catalysis A: General, 171(1), 13–29.
- Kurosaka, T., Maruyama, H., Narabayashi, I., and Sasaki, Y. (2008). Production of 1,3-propanediol by hydrogenolysis of glycerol catalyzed by Pt/WO<sub>3</sub>/ZrO<sub>2</sub>. Catalysis Communications, 9(6), 1360–1363.
- Kurr, P., Kasatkin, I., Girgsdies, F., Trunschke, A., Schlogl, R., Ressler, T. (2008). Microstructural characterization of Cu/ZnO/Al<sub>2</sub>O<sub>3</sub> catalysts for methanol steam reforming—A comparative study. Applied Catalysis A: General, 348(2), 153–164.
- Kusunoki, Y., Miyazawa, T., Kunimori, K., and Tomishige, K. (2005). Highly active metal-acid bifunctional catalyst system for hydrogenolysis of glycerol under mild reaction conditions. Catalysis Communications, 6(10), 645–649.
- Lahr, D.G., and Shanks, B.H. (2003). Kinetic analysis of the hydrogenolysis of lower polyhydric alcohol: Glycerol to glycol. Industrial & Engineering Chemistry Research, 42(22), 5467–5472.
- Lahr, D.G., and Shanks, B.H. (2005). Effect of sulfur and temperature on ruthenium-catalyzed glycerol hydrogenolysis to glycals. Journal of Catalysis, 232(2), 386–394.

- Le Page, J.-F., Cosyns, J., Courty, P., Freund, E., Franck, J.-P., Jacquin, Y., Juguin, B., Marcilly, C., Martino, G., Miquel, J., Montarnal, R., Sugier, A., Van Landeghem, H. (1987). Applied Heterogeneous Catalysis. Paris: IFP.
- López-Suárez, F.E., Bueno-López, A., Illán-Gómez, M.J. (2008). Cu/Al<sub>2</sub>O<sub>3</sub> catalysts for soot oxidation: Copper loading effect. Applied Catalysis B: Environmental, 84(3–4), 651–658.
- Mallat, T., Bodnar, Z., Hug, P., and Baiker, A. (1995). Selective oxidation of cinnamyl alcohol to cinnamaldehyde with air over Bi-Pt/Alumina catalysts. Journal of catalysis, 153(1), 131–143.
- Marchi, J.A., Gordo, D.A., Trasarti, A.F., and Apesteguía, C.R. (2003). Liquid phase hydrogenation of cinnamaldehyde on Cu-based catalysts. Applied Catalysis A: General, 249(1), 53–67.
- Miyazawa, T., Koso, S., Kunimori K., and Tomishige, K. (2007). Glycerol hydrogenolysis to 1,2-propanediol catalyzed by a heat-resistant ion-exchange resin combined with Ru/C. Applied Catalysis A: General, 329(1), 30–35.
- Miyazawa, T., Kusunoki, Y., Kunimori, K., and Tomishige, K. (2006). Glycerol conversion in the aqueous solution under hydrogen over Ru/C + an ion-exchange resin and its reaction mechanism. Journal of Catalysis, 240(2), 213–221.
- Montassier, C., Dumas, J. M., Granger, P., Barbier, J. (1995). Deactivation of supported copper based catalysts during polyol conversion in aqueous phase. Applied Catalysis A: General, 121(2), 231–244.
- Montassier, C., Giraud, D., and Barbier, J. (1988). Polyol conversion by liquid phase heterogeneous catalysis over metals. Studies in Surface Science and Catalysis, 41, 165–170.
- Montassier, C., Me'ne'zo, J.C., Hoang, L.C., Renaud, J., and Barbier, J. (1991). Aqueous polyol conversions on ruthenium and on sulfur-modified ruthenium. Journal of Molecular Catalysis, 70(1), 99–110.
- Moulijn J.A., Diepen, A.E., and Kapteijn, F. (2001). Catalyst deactivation: is it predictable? What to do?. Applied Catalysis A: General, 212(1–2), 3–16.
- Pérez-Hernández, R., Mondragón Galicia, G., Palacios, J., Angeles-Chavez, C., and Arenas-Alatorre, J. (2008). Synthesis and characterization of bimetallic Cu-

- Ni/ZrO<sub>2</sub> nanocatalysts: H<sub>2</sub> production by oxidative steam reforming of methanol. *International Journal of Hydrogen Energy*, 33(17), 4569–4576.
- Perosa A., and Tundo, P. (2005). Selective hydrogenolysis of glycerol with Raney nickel. *Industrial & Engineering Chemistry Research*, 44(23), 8535–8537.
- Saito, M., Fujitani, T., Takeuchi, M., and Watanabe, T. (1996). Development of copper/zinc oxide-based multicomponent catalysts for methanol synthesis from carbon dioxide and hydrogen. *Applied Catalysis A: General*, 138(2), 311–318.
- Schlaf, M., Ghosh, P., Fagan, P. J., Hauptman, E., and Bullock, R.M. (2001). Metal-catalyzed selective deoxygenation of diols to alcohols. *Angewandte Chemie International Edition*, 40, 3887–3890.
- Schuster, L., and Eggersdorfer, M. (1997). Preparation of 1,2-propanediol. *United State Patent*, 5,616,817.
- Schüth, F., and Unger, K. (1997). *Preparation and Coprecipitation, Handbook of Heterogeneous Catalysis*. New York: Wiley-VCH.
- Shishido, T., Yamamoro, Y., Morioka, H., Takaki, K., Takehira, K. (2004). Active Cu/ZnO and Cu/ZnO/Al<sub>2</sub>O<sub>3</sub> catalysts prepared by homogeneous precipitation method in steam reforming of methanol. *Applied Catalysis A: General*, 263(2), 249–253.
- Shishido, T., Yamamoto, M., Li, D., Tian, Y., Morioka, H., Honda, M., Sano, T., Takehira, K. (2006). Water-gas shift reaction over Cu/ZnO and Cu/ZnO/Al<sub>2</sub>O<sub>3</sub> catalysts prepared by homogeneous precipitation. *Applied Catalysis A: General*, 303(1), 62–71.
- Sitthisa, S. (2007). *Dehydroxylation of Glycerol for Propanediols Production*. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University.
- Swangkotchakorn, C. (2008). *Dehydroxylation of Glycerol for Propanediols Production: Catalytic Activity and Stability Testing*. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University.
- Tanaka, Y., Utaka, T., Kikuchi, R., Sasaki, K., Eguchi, K. (2003). CO removal from reformed fuel over Cu/ZnO/Al<sub>2</sub>O<sub>3</sub> catalysts prepared by impregnation and coprecipitation methods. *Applied Catalysis A: General*, 238(1), 11–18.

- Trimm, D.L. (2001). The regeneration or disposal of deactivated heterogeneous catalysts. *Applied Catalysis A: General*, 212(1–2), 153–160.
- Twigg, M.V. and Spencer, M. S. (2001). Deactivation of supported copper metal catalysts for hydrogenation reactions. *Applied Catalysis A: General*, 212(1–2), 161–174.
- Velu, S., Suzuki, K., Gopinath, C.S., Yoshida, H., and Hattori, T. (2002). XPS, XANES and EXAFS investigations of CuO/ZnO/Al<sub>2</sub>O<sub>3</sub>/ZrO<sub>2</sub> mixed oxide catalysts. *Physical Chemistry Chemical Physics*, 4, 1990–1999.
- Wang, K., Hawley, M.C., and DeAthos, S.J. (2003). Conversion of glycrol to 1,3-propanediol via selective dehydroxylation. *Industrial & Engineering Chemistry Research*, 42(13), 2913–2923.
- Wang, Q., Wang, L., Chen, J., Wu, Y., and Mi, Z. (2007). Deactivation and regeneration of titanium silicalite catalyst for epoxidation of propylene. *Journal of Molecular Catalysis A: Chemical*, 273(1–2), 73–80.
- Wang, S. and Liu, H. (2007). Selective hydrogenolysis of glycerol to propylene glycol on Cu–ZnO catalysts. *Catalysis Letters*, 117(1–2), 62–67.
- Yahiro, H., Nakaya, K., Yamamoto, T., Saiki, K., and Yamaura, H. (2006). Effect of calcination temperature on the catalytic activity of copper supported on c-alumina for the water-gas-shift reaction. *Catalysis Communications*, 7(4), 228–231.
- Yang, R., Yu, X., Zhang, Y., Li, W., and Tsubaki, N. (2008). A new method of low-temperature methanol synthesis on Cu/ZnO/Al<sub>2</sub>O<sub>3</sub> catalysts from CO/CO<sub>2</sub>/H<sub>2</sub>. *Fuel*, 87(4–5), 443–450.
- Zhou, C., Beltramini, J.N., Fana, Y., and Lu., G.Q. (2008). Chemoselective catalytic conversion of glycerol as a biorenewable source to valuable commodity chemicals. *Chemical Society Reviews*, 37, 527–549.
- Zhu, X.D., and Hofmann, H. (1996). Deactivation of Ni/SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>-catalyst in hydrogenation of 3-hydroxypropanal solution. *Applied Catalysis A: General*, 155(2), 179–194.

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