CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The ethylation of benzene with ethanol over various synthesized HZSM-5 catalysts was demonstrated as the catalysts which have SiO_2/Al_2O_3 ratios of ca. 195 provide high selectivity to EB. The HZSM-5 catalysts synthesized by various kind of method and conditions provide different features of catalyst especially morphology, textural properties, Brönsted acid site, and SiO_2/Al_2O_3. It was observed that the group of HZSM-5 synthesized by NaOH provided higher EB selectivity, benzene conversion, and EB yield than the group of NH_4F. As the small crystal size, large amount of mesopore, and low Brönsted acid site will provide positive catalytic activity on EB selectivity. Those properties are an advantage of NaOH method superior to the group of NH_4F method. However, the catalysts hydrothermally synthesized at low temperature and time synthesis especially at 120 °C tended to provide a suitable catalyst properties on EB selectivity resulting in a higher EB selectivity observed in a synthesized catalyst at 120 °C for 72 h. Moreover, at high temperature synthesis (140 °C) tended to profit in term of benzene conversion. Notwithstanding, from the results, it was observed that the EB selectivity behaved in opposite direction to benzene conversion which tended to increase with increasing micropore and crystal size, but EB selectivity disfavors those properties, so depending on the purpose of the using that which one is chosen.

In addition, the reaction temperature 400 and 500 °C provided the highest benzene conversion and EB selectivity, respectively. Moreover, with increasing the B/E feed molar ratio from 1 to 4 resulted in decreasing the benzene conversion, whereas, it increased the selectivity to EB and the coke formation, similarly to WHSV, the increment of WHSV from 10 to 20 h^{-1} seem to provided low benzene conversion and high EB selectivity. In conclusion, it is suggested that for ethylation of benzene with ethanol when high EB selectivity is the preference, so using the synthesized HZSM-5 catalyst obtained from synthesized temperature 120 °C for 72 h

with a SiO_2/Al_2O_3 ratio of ca. 195, the optimal parameters be a temperature of 500 °C, a B/E feed ratio of 4:1, and WHSV of 20 h^{-1}. However, the HZ5-B2(40) synthesized at crystallization temperature of 120 °C and time of 72 h with a H_2O/SiO_2 of 40 exhibits the most pronounced activity under the specified reaction condition amongst the synthesized ones. This is probably because of the dominance in micropore to total pore volume and appropriate amounts of Brönsted acid sites. The benzene conversion and yield of EB was observed to increase as a decrease in mesopore and an increase appropriately in Brönsted acid site.

5.2 Recommendations

From the goal of this research is to gain more or less complete EB selectivity. However, this research had overcome the target only 94.91% EB selectivity, as nearby the previous work that approach it only 94.13% EB selectivity. In the author's notion, it is the challenge to overcome 5% remaining and pass up to 100%. Moreover, it is impossible to avoid many secondary reactions. Nevertheless, all problems always have solutions, but the author observed that the solution of play in the temperature and time of synthesis is no longer a key of problem solving to success in the purpose of 100% of EB selectivity. The assumption about synthesis time and temperature started from Duang-udom's work, 2011, which has chosen 150 and 180 °C as a synthesis temperature, the result showed the only highest EB selectivity of 94.13% at 150 °C of synthesis, the author observed that the tendency of EB selectivity be in positive if the temperature below 150 °C was performed. So, the author had decided to play in the range of temperature as below 150 °C, those one is 120 °C and then 140 °C. However, the catalytic activity 120 °C and 140 °C still have not shown the approaching to 100% EB selectivity. Therefore, with clearly shown results, the author rightly conclude that a play in the temperature and time is not a suitable solution to meet the highest goal of 100% EB selectivity, but the important thing is to find any additives which can effectively suppress the secondary reactions.