

## CHAPTER V

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

Indium-containing ZSM-5 is a selective catalyst for direct methylation of benzene with methane to desired aromatic products like toluene and xylene. In/HZSM-5 treated with hydrogen at 700 °C prior to the oxidative reaction provided higher benzene conversion than non-oxidative reaction however the toluene selectivity is significantly dropped. The different treatment atmospheres play an important role in the behavior of active species  $\text{InO}^+$ . The high amount of indium loading provided high benzene conversion and toluene selectivity due to the higher amount of indium cation active species. The reaction condition; reaction temperature, space velocity or methane to benzene feed ratio are also affect to the benzene conversion and toluene selectivity which are described by the thermodynamic principles. In/HZSM-5 with  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio 50 provides the highest benzene conversion and high toluene selectivity which refers as the good balancing between Lewis and Brønsted acid site.

## 5.2 Recommendations

The catalyst preparation for the metal loading techniques such as impregnation and liquid ion exchange should be studied to compare with the solid-state ion exchange technique. In this experiment, a mortar, which was used to mix HZSM-5 with  $\text{In}_2\text{O}_3$ , was not good equipment to prepare catalysts. The better mixing method should be performed by using ball mill technique.

The other metal loaded on catalyst should be studied because it might provide the different activity from the different precursor.

The characterization was also not completely clear for examining the exact active species, the pyridine adsorption technique or XPS should be the attractive techniques to confirm the indium species.