

Catalytic Performance of Supported Copper based Bimetallic Catalysts for Deep Oxidation of Toluene

Young-Kwon Park¹, Sang Chul Jung², Wang Geun Shim³, Seong Gyu Seo⁴, Sang Chai Kim^{5*}

¹School of Environmental Engineering, University of Seoul, Seoul 02504, Korea

²Department of Environmental Engineering, Suncheon National University, Suncheon, 57975, Korea

³Department of Polymer Engineering, Suncheon National University, Suncheon, 57975

⁴Division of Civil and Environmental Engineering, Chonnam National University, Yeosu 55749, Korea

⁵Department of Environmental Education, Mokpo National University 61, Muan 58554, Korea

*Corresponding author: gikim@mokpo.ac.kr

Highlights

- Supported bimetallic catalysts were prepared for toluene oxidation.
- 5 wt% Cu/ γ -Al₂O₃ served as a parent catalyst.
- Combination of transition metals brought about promoting the catalytic activity for oxidation.

1. Introduction

The reduction of VOCs emission is a major concern of the industries' commitment towards the environment and human health [1]. Deep oxidation of volatile organic compounds (VOCs) by using a catalytic system has been known as one of the most respectable techniques for their abatement due to its lower operation temperature which effectively reduces energy cost and amounts of toxic products [2, 3]. In this work, we investigated the catalytic performance of supported bimetallic catalysts incorporating transition metals instead of incorporating at least one metal from precious metal. Accordingly, we used 5 wt% Cu/ γ -Al₂O₃ catalyst as a parent catalyst, and incorporated transition metals (Mn, Co, Cr and Fe) with the parent catalyst. Aromatic compound (toluene) was selected for complete oxidation of VOCs because it is one of the major pollutants exhausted from stationary sources. The changes in the physicochemical states of the catalysts were also examined by instrumental analysis.

2. Methods

The catalysts were prepared by the conventional impregnation method using aqueous solutions of copper (Cu) nitrate, transition metal (M = Mn, Cr, Co and Fe) nitrates and γ -Al₂O₃ (100-150 mesh and 155m²g⁻¹) as a support. Each catalyst was denoted xCu/Al, xM/Al or xCu-x/Al, where x is the weight percent of copper loading and transition metal loading on γ -Al₂O₃. The catalytic oxidations were carried out using a conventional fixed bed flow reactor [4]. The catalytic reactor (quartz tube with the shape of a I) was consisted of a vertical tubular with 1.0 cm diameter and 35 cm length in an electrical heating system controlled by a proportional integral derivative (PID) controller. In order to get an accurate measurement of the catalyst temperature, K type thermocouple was positioned in the catalyst bed. A catalyst sample of 0.2 g was loaded in the middle of the reactor supported by quartz wool.

3. Results and discussion

Figure 1 compares the toluene conversions for supported monometallic catalysts and bimetallic catalysts at temperatures of 240-470 °C. The light-off curves of toluene oxidation exhibit that the catalytic activity of the supported bimetallic catalyst is significantly dependent on the combination of transition metals. Though the toluene conversion of 5Mn/Al, 5Cr/Al, 5Fe/Al, or 5Co/Al catalyst was lower than that of 5Cu/Al catalyst, incorporating Mn, Cr, Fe or Co with 5 Cu/Al catalyst brought about promoting its catalytic activity on the basis of T₉₀ conversion (the value of the temperature at conversion approaches 90%), which were 310 °C for 5Mn-5Cu/Al, 317 °C for 5Cr-5Cu/Al, 337 °C for 5Fe-5Cu/Al and 338 °C for 5Co-5Cu/Al compared to 363 °C for 5Cu/Al. These results showed that the catalytic activities with respect to incorporating different transition metals with 5Cu/Al were in the order 5Cu-5Mn/Al > 5Cu-5Cr/Al > 5Cu-5Fe/Al > 5Cu-5Co/Al > 5Cu/Al on the basis of T₉₀ conversion.

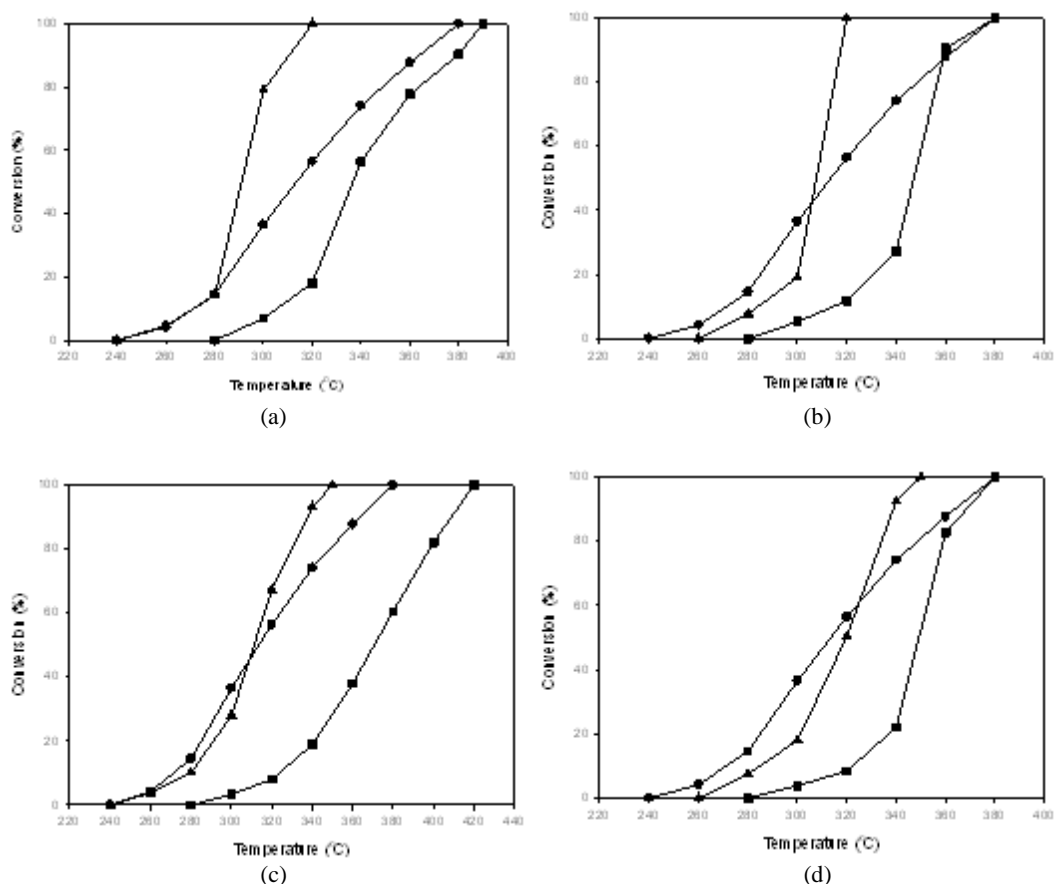


Figure 1. Toluene conversion over different catalysts.

Reaction condition: catalyst weight = 0.2 g, toluene concentration = 1,000 ppm.,
GHSV = 55,000 hr⁻¹.

(a) ● 5Cu/Al, ■ 5Mn/Al ▲ 5Cu-5Mn/Al (b) ● 5Cu/Al, ■ 5Cr/Al ▲ 5Cu-5Cr/Al
(c) ● 5Cu/Al, ■ 5Fe/Al ▲ 5Cu-5Fe/Al (d) ● 5Cu/Al, ■ 5Co/Al ▲ 5Cu-5Co/Al

4. Conclusions

The catalytic activity of supported bimetallic catalysts was in the order 5Cu-5Mn/Al > 5Cu-5Cr/Al > 5Cu-5Fe/Al > 5Cu-5Co/Al > 5Cu/Al based on T₉₀ of toluene conversion. Two different reaction mechanisms were present in the toluene oxidation over these catalysts. That is, the mixing effect of two different transition metals dominated the catalytic reaction at low temperatures (below ≈300 °C), whereas the synergistic effect played an important role in the catalytic reaction at relatively high temperatures.

References

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Keywords

Oxidation, VOCs, Catalyst, Bimetal