Steam reforming of ethanol over RhPt/CeO₂ for H₂ production: Influence of the Rh:Pt ratio on the catalytic activity and selectivity

Bernay Cifuentes and Martha Cobo

Chemical Engineering Department, Universidad de La Sabana, Km. 7 Autopista Norte, Bogotá, Colombia

*martha.cobo@unisabana.edu.co

Introduction

Hydrogen from ethanol is regarded as a promising model to produce sustainable energy for automobile applications in the future. Pt and Rh over CeO₂ have been proposed as a favorable catalyst to enhance activity and H₂ selectivity with less coke formation in the steam reforming of ethanol (SRE). In this study, RhPt/CeO₂ catalysts with different Rh:Pt ratios were evaluated in the SRE in order to determine its influence on the catalytic activity and product distribution.

Materials and Methods

RhPt with different weight Rh:Pt ratios (1:0, 3:1, 1:1 and 0:1) over CeO₂ (Alfa Aesar, USA) catalysts were prepared by incipient wetness impregnation, dried at 105 °C, calcined in muffle at 700 °C and sieved to obtain particles smaller than 0.17 mm. The total metal loading was 0.8 wt% in all catalysts. Before reaction, catalyst samples were reduced in 10% H₂/N₂ at 700 °C for 1 h. The SRE was conducted at atmospheric pressure in a tubular fixed bed reactor. The outlet stream composition was quantified using a GC Clarus 580 (Perkin Elmer, USA).

Results and Discussion

Figure 1a shows the conversion vs. temperature profile of the studied ceria-supported catalysts. With increasing temperature, the catalysts reached 100% ethanol conversion in the order of RhPt (3:1, 520 °C), RhPt (1:1, 600 °C), Rh (640 °C) and Pt (700 °C). Both bimetallic RhPt/CeO₂ catalysts presented the highest activity on the SRE showing a synergistic effect between Rh and Pt [1]. Figure 1b shows H₂ yield for the four catalysts. At 700 °C, the bimetallic catalysts RhPt (1:1) and RhPt (3:1) showed the highest H₂ production, with values of 4.3 and 4.1 mole of H₂/mole of ethanol, respectively, close to the thermodynamic limit (4.4).

Pt/CeO₂ showed a better performance at low temperature than Rh/CeO₂, probably because of a major presence of the water–gas shift reaction (WGSR) promoted by Pt at low temperature [2]. This is consistent with the product distribution shown in figure 2. The behavior of the catalysts is strongly influenced by the Rh:Pt ratio. In this way, CO was lower and CO₂ was higher on catalysts with higher content of Pt, possibly due to the tendency of Pt to oxidase C–O species [3]. By contrast, the increase in the amount of Rh on the catalysts promoted lower concentrations of methane and ethane when the temperature decreases as it promotes the reforming of these compounds [2]. Bimetallic catalyst RhPt(1:1)/CeO₂ showed the better H₂ selectivity at high temperatures (>500 °C) with average concentrations of CO₂ and low formation of CO, methane, ethane and ethylene. Likewise, below 500 °C RhPt(1:1)/CeO₂ presented a similar behavior of Pt/CeO₂ maintaining a low production of CO, suggesting that probably it promotes WGSR at these temperatures. This is desirable when thinking in an automobile application, when the operating temperature is constantly changing.

Significance

RhPt(1:1)/CeO₂ was found to be a promising catalyst for the SRE because it showed a higher catalytic activity and H₂ selectivity than the monometallic samples. This catalyst showed the properties of Rh catalyst to promote SRE at higher temperature and of Pt to promote WGSR at lower temperatures. This feature can be interesting in automobile applications to control the catalyst performance under changing operation conditions.

References