

Development and Enhancement of Iron-Based Catalysts to Boost the Conversion of CO₂ via Fischer-Tropsch-Synthesis

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Abstract

Major challenges for climate change are the sustainable production of liquid fuels from renewable resources. One option is the use of CO₂ from various sources (power plants, chemical industry, and potentially separated from air) and the subsequent conversion with renewable hydrogen to higher hydrocarbons (HCs). For the activation and conversion of CO₂ into higher hydrocarbons (HCs), conventional power-to-liquid (PTL) plants may be used. But current PTL-systems include a two-stage system at which in the first step, CO₂ and H₂ are converted into CO and H₂O by the reverse-water-gas-shift reaction (RWGS). Only subsequently, higher HCs are synthesized via Fischer-Tropsch-synthesis (FTS).

At moderate temperatures (about 220 °C) the conversion of CO₂ is limited to 10 to 20 % by the endothermic RWGS reaction by thermodynamic limitations, depending on the H₂/CO₂-ratio. Since the FTS reaction is strongly exothermic and may substantially convert CO from the RWGS reaction, higher conversions of CO₂ are in principle possible. A suitable catalyst should therefore have reaction rates high enough for RWGS and an even higher rate for the FTS reaction. Furthermore, the catalyst should in general also have a low selectivity to methane.

Many studies have shown that one potential way to directly convert CO₂ with H₂ to higher HCs is by the use of iron-based catalysts. These catalysts contain different active sites (iron oxides + iron carbides) which perform the two catalytic reactions (RWGS+FTS) simultaneously. The FTS reaction takes place on the iron carbides and leads to the formation of a variety of hydrocarbons following the Anderson-Schulz-Flory distribution (ASF).

In this study, iron-based sinter-catalysts were investigated for their activity and selectivity to higher hydrocarbons. The catalysts were tested under Fischer-Tropsch conditions (T = 220 °C, p = 20 bar, H₂/CO₂ = 2). The results showed that iron-sintered catalysts are potentially able to convert CO₂ at moderate reaction conditions to higher hydrocarbons with still a low selectivity to methane. Further studies on the modification of the catalyst composition as well as the variation of the H₂/CO₂-ratios showed that the effectiveness of iron-sintered catalysts can be selectively enhanced by the appropriate choice of promoters and reaction conditions.