

Ruthenium Catalyzed Hydrogenation of Carbon Dioxide to *N,N*-dimethylformamide in Miniplant Scale – Potential and Challenges

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Abstract

The utilization of carbon dioxide as C₁-building block for valuable chemicals is an attractive alternative to common carbon sources.^[1] Due to its abundance and high concentrations in flue gas, carbon dioxide can be obtained with low costs. Since CO₂ is non-toxic and non-flammable it turns out to be an attractive green chemical. Therefore, the utilization of carbon dioxide as surrogate for toxic components such as carbon monoxide, e.g. for the synthesis of formamides, is favorable. The synthesis of formamides with CO₂ involves the homogeneous catalyzed hydrogenation of carbon dioxide (Figure 1).

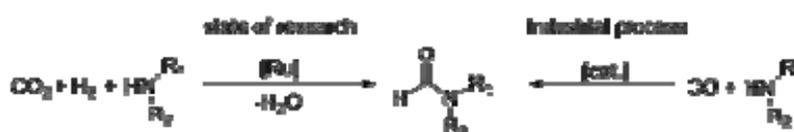


Figure 1: Synthesis of formamides

While the reaction system is well investigated in the laboratory,^[2] the scale up into a continuous process (Figure 2) is still a critical challenge especially regarding the handling of carbon dioxide in the process. Investigations show that an *in situ* generated catalyst can be easily and effectively recycled by a liquid-liquid multiphase system with a ruthenium recovery rate of 97% using a RuCl₃/BISBI catalyst complex. Further research using the catalyst complex Ru-Macho, which has shown higher long term stability in batch experiments, allowed a targeted investigation of the carbon dioxide absorption behavior in the continuous process. Eventually adjusting parameters like the CO₂/H₂ gas ratio and doing main mechanically changes in the continuous process makes it now possible to successfully scale up the reaction. Overcoming enormous technical difficulties resulted in a long term stable process of 235 hours, while at the same time having only a catalyst leaching of 0,02% per hour.

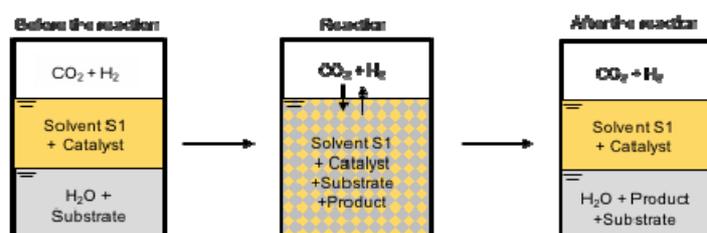


Figure 2: Reaction steps in the continuous process

Literature:

[1] Q. Liu, L. Wu, R. Jackstell, M. Beller, *Nat. Commun.* **2015**, *6*, 5933.

[2] O. Kröcher, R. A. Köppel, A. Baiker, *Chem. Commun.* **1997**, 453–454.