CHEMICALS

Project Fact Sheet

Biphasic Hydroformylation of Higher Olefins

Benefits

- Efficient hydroformylation of higher olefins to make long-chain aldehydes
- Energy savings of more than 8 trillion Btu per year by 2020
- Feedstock savings of 30 percent

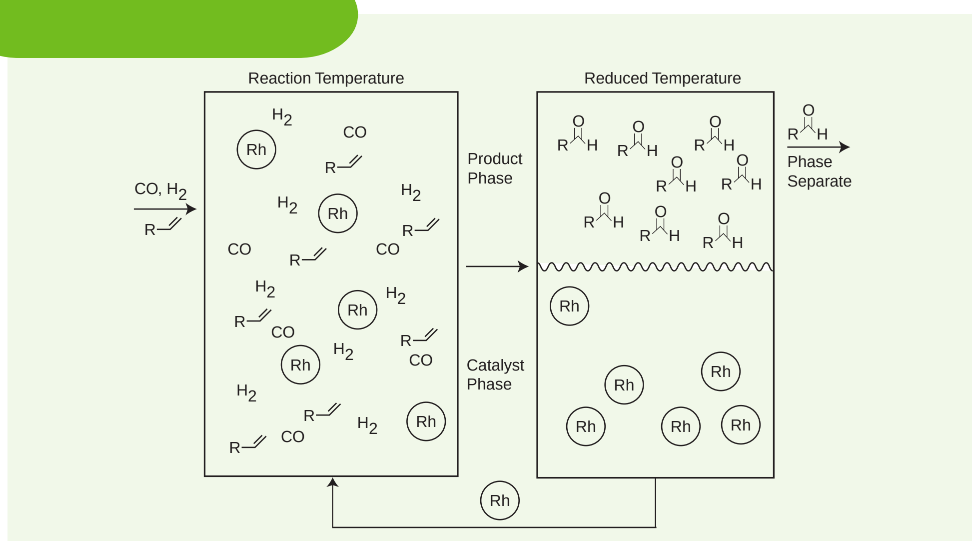
Applications

The primary application of this thermomorphic catalyst system is the production of higher aldehydes using more active and selective rhodium catalysts. The general methodology of this catalyst system could also be used in other chemical processes that use expensive homogeneous catalysts.

New Catalyst Technology for Producing Higher Aldehydes using Rhodium Catalysts

Higher aldehydes are important intermediates in the synthesis of industrial solvents, biodegradable detergents, surfactants, lubricants, and other plasticizers. The process, called hydroformylation or the 'oxo process', refers to the addition of hydrogen and the formyl group, CHO, across a double bond. Current worldwide production of these aldehydes exceeds 7 million tons per year. For lower aldehydes, homogeneous rhodium-phosphine catalysts are used because they have the best activity and selectivity. Lower aldehyde products are recovered by distillation before the catalyst is recycled. The process used for conventional hydroformylation of short-chain alkenes cannot be applied to higher ($>C_6$) olefins due to the difficulty of recovering the high-boiling product aldehyde without simultaneously destroying the catalyst. The hydroformylation of higher olefins ($>C_6$) is done with less efficient cobalt catalysts at high temperatures and pressures.

A thermomorphic catalyst system will eliminate the need to recover the product by distillation and allow the use of much more active and selective rhodium catalysts that will result in significant reduction of feedstock costs and substantial energy savings. These mixtures are immiscible at room temperature but become miscible at reaction temperature, enhancing conversion rates by promoting contact between the rhodium catalyst and the olefin. After the reaction is complete, the reaction mixture is cooled and the phases completely separate. The product can be recovered by decantation and the catalyst can be recycled. Thermomorphic mixtures can result in dramatic energy and cost savings because the fraction of feedstocks converted to the desired product will be increased from 60 to 85 percent.



Representation of hydroformylation in a thermomorphic system.

Project Description

Goal: The goal of this project is to develop a thermomorphic approach to rhodium-catalyzed hydroformylation of higher olefins (>C_6) that enhances conversion rates and ease of product recovery while minimizing catalyst degradation and loss.

The thermomorphic biphasic hydroformylation system being developed in this project has been refined by study of the rhodium-catalyzed hydroformylation of 1-octene and recovery of the product, nonanal. Variables such as solvent polarity, the ever-changing composition of the organic phase as the product forms, and reaction temperature are manipulated to obtain the highest possible conversion rates and selectivity. The durability of the catalyst is measured through cycling the catalyst phase several times and comparing conversion rates from each reaction. The approach is versatile enough that it can be adapted to the hydroformylation of even higher olefins like dodecene.

Progress and Milestones

Significant progress has been made in the following areas:

- Development of a process that is suitable for conversion of higher olefins to higher aldehydes, namely 1-octene to nonanal.
- Achievement of high conversion rates and selectivity due to miscibility-enhancing additives.
- Maintaining little to no leaching and high recyclability of the rhodium catalyst.

Future research focuses on achieving the following milestones:

- Design and construction of a bench-scale prototype reactor.
- Demonstrate the catalyst's durability and tendency not to leach over many cycles.
- Apply the process to other higher olefins, such as dodecene

Project Partners

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