Making hydrogenation greener

June 27 2013

Researchers from McGill University, RIKEN (The Institute of Physical and Chemical Research, Wako, Japan) and the Institute for Molecular Science (Okazaki, Japan) have discovered a way to make the widely used chemical process of hydrogenation more environmentally friendly – and less expensive.

Hydrogenation is a chemical process used in a wide range of industrial applications, from food products, such as margarine, to petrochemicals and pharmaceuticals. The process typically involves the use of heavy metals, such as palladium or platinum, to catalyze the chemical reaction. While these metals are very efficient catalysts, they are also non-renewable, costly, and subject to sharp price fluctuations on international markets.

Because these metals are also toxic, even in small quantities, they also raise environmental and safety concerns. Pharmaceutical companies, for example, must use expensive purification methods to limit residual levels of these elements in pharmaceutical products. Iron, by contrast, is both naturally abundant and far less toxic than heavy metals.

Previous work by other researchers has shown that iron nanoparticles—tiny pieces of metallic iron—can be used to activate the hydrogenation reaction. Iron, however, has a well-known drawback: it rusts in the presence of oxygen or water. When rusted, iron nanoparticles stop acting as hydrogenation catalysts. This problem, which occurs with so much as trace quantities of water, has prevented iron nanoparticles from being used in industry.

In research published today in the journal *Green Chemistry*, scientists from McGill, RIKEN, and the Institute for Molecular Science report that they have found a way to overcome this limitation, making iron an active catalyst in water-ethanol mixtures containing up to 90% water.

The key to this new method is to produce the particles directly inside a polymer matrix, composed of amphiphilic polymers based on polystyrene and polyethylene glycol. The polymer acts as a wrapping film that protects the iron surface from rusting in the presence of water, while allowing the reactants to reach the water and react.

This innovation enabled the researchers to use iron nanoparticles as catalyst in a flow system, raising the possibility that iron could be used to replace platinum-series metals for hydrogenation under industrial conditions.

"Our research is now focused on achieving a better understanding of how the polymers are protecting the surface of the iron from water, while at the same time allowing the iron to interact with the substrate," says Audrey Moores, an assistant professor of chemistry at McGill and co-corresponding author of the paper.

The results stem from an ongoing collaboration between McGill and RIKEN, one of Japan's largest scientific research organizations, in the fields of nanotechnology and green chemistry. Lead author Reuben Hudson, a doctoral student at McGill, worked on the project at the RIKEN Center for Sustainable Resource Science and at the Institute for Molecular Science in Japan. Co-authors of the paper are Prof. Chao-Jun Li of McGill, Dr. Go Hamasaka and Dr. Takao Osako of the Institute for Molecular Science, Dr. Yoichi M.A. Yamada of Riken and Prof. Yasuhiro Uozumi of Riken and the Institute for Molecular Science.

"The approach we have developed through this collaboration could lead to more sustainable industrial processes," says Prof. Uozumi. "This technique provides a system in which the reaction can happen over and over with the same small amount of a catalytic material, and it enables it to take place in almost pure water—the green solvent par excellence."

More information: xlink.rsc.org/?doi=10.1039/C3GC40789F

Provided by McGill University