Engineers find greener path to making key industrial chemical

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Tulane chemical engineer Matthew Montemore found that adding small amounts of nickel atoms to silver catalysts can maintain production efficiency of a crucial chemical used in everyday products. (Photo by Vincent Postle)

Scientists have discovered a potentially greener way to produce a crucial industrial chemical used to make many everyday products from plastics and textiles to antifreeze and disinfectants, according to a new study published in *Science* and co-authored by Tulane University chemical engineer Matthew Montemore.

The breakthrough could significantly reduce greenhouse gas emissions from the manufacture of ethylene oxide, which has an estimated $40 billion global market. The current production process requires chlorine, which is toxic and emits millions of tons of carbon dioxide into the atmosphere annually.

The research team, led by Montemore, as well as Tufts University chemistry professor Charles Sykes and University of California Santa Barbara (UCSB) chemical engineering professor Phillip Christopher, found that adding small amounts of nickel atoms to silver catalysts can maintain production efficiency while eliminating the need for chlorine in the process.

“If industry does try this out and they find it to be useful and are able to commercialize it, the twin benefits are you can save a lot of CO2 and a lot of money at the same time,” Montemore said.

Getting rid of toxic chlorine could also make production safer, Montemore added.

The discovery was six years in the making. Sykes and Montemore first discussed exploring selective oxidation reactions in 2018. They focused on ethylene oxide production, which converts ethylene and molecular oxygen using silver as the primary catalyst.

"We were surprised because we couldn't find anything in the scientific or patent literature about nickel despite it being a common and inexpensive element used in many other catalytic processes," Sykes said.

The breakthrough came through applying Sykes' single-atom alloy concept, a fundamental approach to understanding and controlling chemical reactions that he pioneered over a decade ago. Montemore thought this approach could be applied to oxidation reactions, even though Sykes had not had much success with oxidation in the past.

Montemore performed calculations to screen for promising combinations of metals. Based on these calculations, PhD students Elizabeth Happel and Laura Cramer at Tufts conducted initial experiments that showed promising results.

The team then enlisted Christopher, an expert on catalytic reactor studies, to develop a practical formulation of the silver catalyst with nickel additions.

The results exceeded expectations.

Anika Jalil, a doctoral student at UCSB successfully developed a reproducible method for incorporating nickel atoms into the silver catalyst, a technical challenge that may explain why this effect had never been previously reported.

The current industrial process for producing ethylene oxide typically generates two molecules of carbon dioxide per ethylene oxide molecule. Adding chlorine improves this ratio to about two molecules of ethylene oxide per carbon dioxide molecule. The new nickel-enhanced catalyst could potentially reduce these emissions further.

The team has submitted international patents for its discovery and is in discussions with a major commercial producer about implementing the technology in existing manufacturing facilities.

If successful, this cleaner production method could help address the significant environmental impact of ethylene oxide manufacturing while maintaining the efficiency needed for industrial-scale production.