

Chemists discover new way to harness energy from ammonia

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A research team at the University of Wisconsin-Madison has identified a new way to convert ammonia to nitrogen gas through a process that could be a step toward ammonia replacing carbon-based fuels.

The discovery of this technique, which uses a metal [catalyst](#) and

releases—rather than requires—energy, was reported Nov. 8 in *Nature Chemistry* and has received a provisional patent from the Wisconsin Alumni Research Foundation.

"The world currently runs on a carbon fuel economy," explains Christian Wallen, an author of the paper and a former postdoctoral researcher in the lab of UW-Madison chemist John Berry. "It's not a great economy because we burn hydrocarbons, which release carbon dioxide into the atmosphere. We don't have a way to close the loop for a true carbon cycle, where we could transform carbon dioxide back into a useful fuel."

To move toward the United Nations' goal for the world to become carbon-neutral by 2050, scientists must consider environmentally responsible ways to create energy from elements other than carbon, and the UW-Madison team is proposing a nitrogen energy economy based on interconversions of nitrogen and [ammonia](#).

The scientists were excited to find that the addition of ammonia to a metal catalyst containing the platinum-like element ruthenium spontaneously produced nitrogen, which means that no added energy was required. Instead, this process can be harnessed to produce electricity, with protons and nitrogen gas as byproducts. In addition, the metal complex can be recycled through exposure to oxygen and used repeatedly, all a much cleaner process than using carbon-based fuels.

"We figured out that, not only are we making nitrogen, we are making it under conditions that are completely unprecedented," says Berry, who is the Lester McNall Professor of Chemistry and focuses his research efforts on transition metal chemistry. "To be able to complete the ammonia-to-nitrogen reaction under ambient conditions—and get energy—is a pretty big deal."

Ammonia has been burned as a fuel source for many years. During

World War II, it was used in automobiles, and scientists today are considering ways to burn it in engines as a replacement for gasoline, particularly in the maritime industry. However, burning ammonia releases toxic nitrogen oxide gases.

The new reaction avoids those toxic byproducts. If the reaction were housed in a fuel cell where ammonia and ruthenium react at an electrode surface, it could cleanly produce electricity without the need for a catalytic converter.

"For a fuel cell, we want an electrical output, not input," Wallen says. "We discovered chemical compounds that catalyze the conversion of ammonia to nitrogen at room temperature, without any applied voltage or added chemicals. This is the first process, as far as we know, to do that."

"We have an established infrastructure for distribution of ammonia, which is already mass produced from nitrogen and hydrogen in the Haber-Bosch process," says Michael Trenerry, a graduate student and author on the paper. "This technology could enable a carbon-free fuel economy, but it's one half of the puzzle. One of the drawbacks of ammonia synthesis is that the hydrogen we use to make ammonia comes from natural gas and fossil fuels."

This trend is changing, however, as ammonia producers attempt to produce "green" ammonia, in which the hydrogen atoms are supplied by carbon-neutral water electrolysis instead of the energy-intensive Haber-Bosch process.

As the ammonia synthesis challenges are met, according to Berry, there will be many benefits to using ammonia as a common energy source or fuel. It's compressible, like propane, easy to transport and easy to store. Though some ammonia fuel cells already exist, they, unlike this new

process, require added [energy](#), for example, by first splitting ammonia into [nitrogen](#) and hydrogen.

The group's next steps include figuring out how to engineer a [fuel cell](#) that takes advantage of the new discovery and considering environmentally friendly ways to create the needed starting materials.

"One of the next challenges I would like to think about is how to generate ammonia from water, instead of [hydrogen](#) gas," Trenerry says. "The dream is to put in water, air and sunlight to create a fuel."

More information: Michael J. Trenerry et al, Spontaneous N₂ formation by a diruthenium complex enables electrocatalytic and aerobic oxidation of ammonia, *Nature Chemistry* (2021). [DOI: 10.1038/s41557-021-00797-w](#)

Provided by University of Wisconsin-Madison

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