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A safe synthesis of hydrogen peroxide inspired by nature

A new homogeneous catalyst enables the safe and direct synthesis of hydrogen peroxide

Fukuoka, Japan—Hydrogen peroxide is a ubiquitous chemical found in most homes and used in everything from dying hair to treating wounds. It is also an invaluable agent for many industries from food, textiles, and even in semiconductor production.

Reporting in *JACS*, researchers at Kyushu University have developed a new process to synthesize this chemical utilizing a new homogeneous catalyst inspired by nature. Moreover, the process is significantly safer than conventional methods.

Scientists have been reporting the synthesis of hydrogen peroxide for more than two hundred years. Today's industry standard is a method known as the 'anthraquinone method,' a stepwise and indirect process that dates back to World War II. However, while hydrogen peroxide—or H_2O_2 —itself is relatively harmless, its production sometimes is not.

"Current synthesis methods are wasteful. This is a result of the high flammability of the hydrogen and oxygen mixtures and the requirement of varying materials," explains Professor Seiji Ogo from Kyushu University's Faculty of Engineering, who authored the study.

Ogo and his team have been seeking a greener approach for H_2O_2 production, looking to nature for inspiration. They focused particularly on a set of enzymes called 'hydrogenases.' These are enzymes found in extremophile microorganisms—organisms that live in extremely hostile environments, like the very bottom of the ocean.

Another location of extremophile activity is the hot springs of Japan. This is where Ogo and colleagues found hydrogenase S-77. Hydrogenases show promising properties for the transfer of electrons from hydrogen to oxygen molecules, a key event for the synthesis of hydrogen peroxide.

"Hydrogenase S-77 was the source of inspiration for previous work in my lab, where we constructed a rhodium-based homogeneous catalyst," explains Ogo. "The catalyst worked by facilitating the withdrawal of electrons from hydrogen molecules and then donating them to oxygen molecules. However, it gave a poor yield."

In their new study, the catalyst was improved by incorporating a N-heterocyclic carbene ligand for the reduction stage, which led to a turnover number—a reflection of the efficiency of the reaction—more than 250 times higher than that of the previous catalyst, and one of the highest ever reported for a homogeneous catalyst.

Further, unlike the conventional anthraquinone method, the new homogeneous catalyst requires only one step and no separation of hydrogen and oxygen gas from the reaction flask. Therefore, with more development, the new catalyst could lead to a process that demands

less material and lower costs at industrial levels.

"The new process is an ideal reaction for hydrogen peroxide synthesis because it involves a safe reaction mixture, reaction in one vessel, and direct synthesis using only hydrogen and oxygen," concludes Ogo. "Companies are always seeking ways to lower production costs. Our catalyst may be an important resource for many industries."

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For more information about this research, see "Safe, One-Pot, Homogeneous Direct Synthesis of H₂O₂" Seiji Ogo, Takeshi Yatabe, Tamon Tome, Riko Takenaka, Yoshihito Shiota, and Kenji Kato, *JACS*, <https://doi.org/10.1021/jacs.2c13149>

About Kyushu University

[Kyushu University](#) is one of Japan's leading research-oriented institutes of higher education since its founding in 1911. Home to around 19,000 students and 8,000 faculty and staff, Kyushu U's world-class research centers cover a wide range of study areas and research fields, from the humanities and arts to engineering and medical sciences. Its multiple campuses—including one of the largest in Japan—are located around Fukuoka City, a coastal metropolis on the southwestern Japanese island of Kyushu that is frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Through its [Vision 2030](#), Kyushu U will 'Drive Social Change with Integrative Knowledge.' Its synergistic application of knowledge will encompass all of academia and solve issues in society while innovating new systems for a better future.

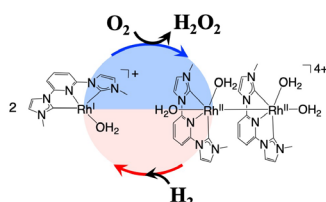


Fig. 1. The safer production of H₂O₂. Inspired by hydrogenases in nature a Kyushu University research team has developed a new catalyst that can synthesize hydrogen peroxide, H₂O₂, in a safe and efficient manner. By adding N-heterocyclic to the rhodium-based homogeneous catalyst they developed in the past the research team was able to increase H₂O₂ production 250-fold. (Ogo Lab/Kyushu University)

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