

OXYGEN EVOLUTION REACTION

Manganese's resilience is key to its use as a catalyst

Researchers have discovered why manganese is an effective catalyst for a key reaction in photosynthesis

It's rather curious that manganese is the key catalyst in one of nature's crucial chemical reactions rather than similar, more plentiful elements such as iron. RIKEN researchers may have discovered the reason why¹. This finding could have implications for generating renewable energy.

The oxygen evolution reaction is crucial for life on Earth since it lies at the heart of photosynthesis. It uses energy to liberate protons and electrons from water—freeing oxygen in the process, which we and other life forms breathe.

Manganese, in the form of oxide-like manganese clusters, is the main catalyst in this reaction. The manganese in this cluster can exist in various oxidation states.

When solar or electrical energy fluctuates, manganese's oxidation state changes, allowing it to drive the reaction repeatedly. The cyclic nature of this process is a key feature for sustainable reactions, as it allows catalysts to be used over and over.

For an ideal catalyst, this process could be repeated indefinitely. However, real catalysts deactivate over time, due to processes such as the dissolution of manganese ions. This is usually a one-way path, and the lost ions do not return to the catalyst.

Now, a team led by Ryuhei Nakamura of the RIKEN Center for Sustainable Resource Science has incorporated the Guyard reaction—in which the oxidation state of the manganese ion changes from seven to three.

When the Guyard reaction



RIKEN researchers have discovered why plants use the metal manganese as a catalyst for the oxygen-evolution reaction in photosynthesis.

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was incorporated, the catalyst decomposed as expected when the voltage became too high, but it was regenerated when the excess voltage was removed. This highlights the importance of pathway design for sustainable energy conversion from intermittent renewable sources.

This regeneration is unique

to manganese, since similar chemical elements in the 3d block of the periodic table, such as cobalt, iron and nickel, cannot regenerate under the same experimental conditions. The researchers believe this is a major reason why manganese is the key catalyst in photosynthesis.

“We have shown it is possible to develop materials resistant to fluctuating voltages, with the potential to eventually develop materials that can be used in water electrolyzers—devices that convert water into oxygen and hydrogen—connected directly to renewable energy sources,” says Nakamura. This is because renewable energy sources, such as solar and wind power, fluctuate

on time scales of seconds to hours.

“This is important work, but in order to create industrial applications for this, we would need to be able to extend the lifespan by at least an order of magnitude,” says Nakamura. “We’re tackling this issue now.” ●

Reference

1. Li, A., Ooka, H., Kong, S., Adachi, K., Zhang, Y., Fushimi, K., Hamamoto, S., Oura, M., Kim, S. H., Hashizume, D. *et al.* Oxygen evolution electrocatalysis resilient to voltage fluctuations. *Nature Sustainability* **8**, 1533–1540 (2025).