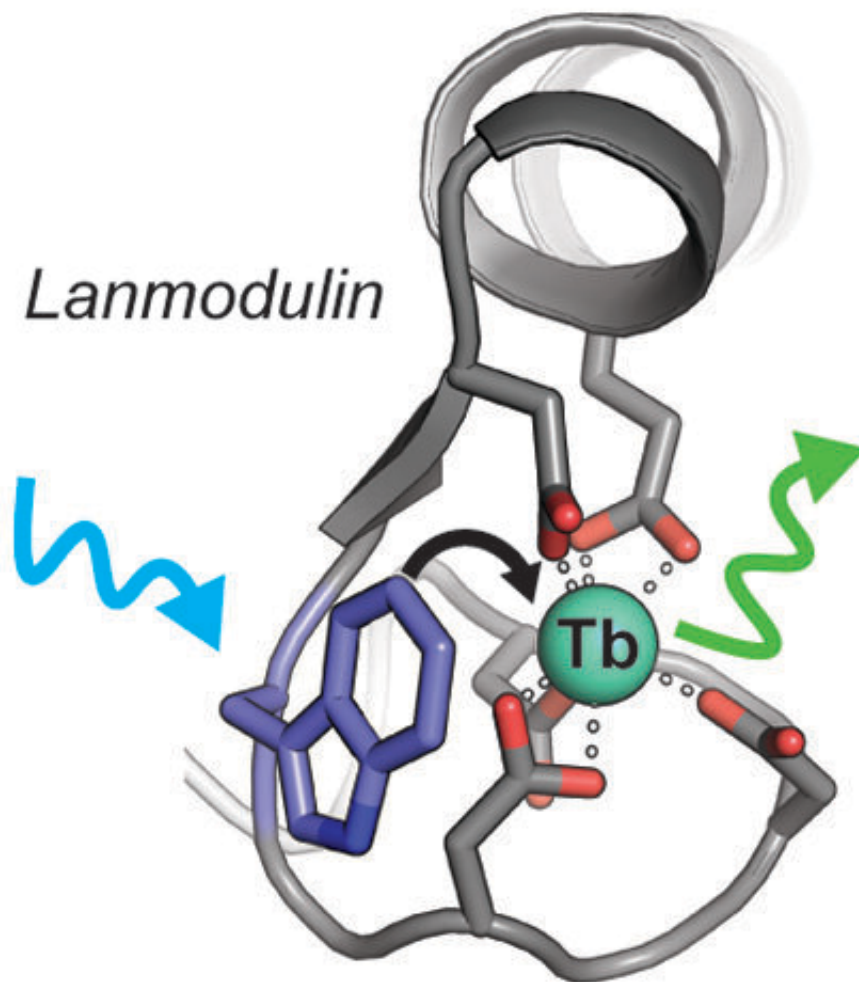


New sensor detects valuable rare earth element terbium from non-traditional sources

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The protein lanmodulin has been developed into a sensor to identify the rare

earth element terbium from complex environments, such as acid mine drainage. The sensor, illustrated here, emits green light when bound to terbium. Credit: Emily Featherston, Penn State

A new luminescent sensor can detect terbium, a valuable rare earth element, from complex environmental samples like acid mine waste. The sensor, developed by researchers at Penn State, takes advantage of a protein that very specifically binds to rare earth elements and could be harnessed to help develop a domestic supply of these metals, which are used in technologies such as smart phones, electric car batteries, and energy efficient lighting. A paper describing the sensor appears Aug. 25 in the *Journal of the American Chemical Society*.

Terbium, one of the rarest of the [rare earth elements](#), produces the green color in cell phone displays and is also used in high-efficiency lighting and solid-state devices. However, there are a variety of chemical, environmental, and political challenges to obtaining terbium and other rare earth elements from the environment. Developing new sources of these metals also requires robust detection methods, which poses another challenge. For example, the gold standard method of detecting rare earth elements in a sample—a type of mass spectrometry called ICP-MS—is expensive and not portable. Portable methods, however, are not as sensitive and do not perform well in complex environmental samples, where acidic conditions and other metals can interfere with detection.

"There is not currently a domestic supply chain of rare earth elements like terbium, but they are actually quite abundant in non-traditional sources in the U.S., including coal byproducts, [acid mine drainage](#), and electronic waste," said Joseph Cotruvo, Jr., assistant professor and Louis Martarano Career Development Professor of Chemistry at Penn State, a member of Penn State's Center for Critical Minerals, and senior author

of the study. "In this study, we developed a luminescence-based sensor that can be used to detect and even quantify low concentrations of terbium in complex acidic samples."

The new sensor relies on lanmodulin, a protein that the researchers previously discovered that is almost a billion times better at binding to rare earth elements than to other metals. The protein's selectivity to bind rare earth elements is ideal for a sensor, as it is most likely to bind to rare earths instead of other metals that are common in environmental samples.

To optimize lanmodulin as a sensor for terbium specifically, the researchers altered the protein by adding the amino acid tryptophan to the protein.



A new sensor could allow researchers to detect the rare earth element terbium from complex environmental samples, such as acid mine drainage—pictured

here polluting a Pennsylvania stream. Credit: Rachel Brennan, Penn State

"Tryptophan is what is called a 'sensitizer' for terbium, which means that light absorbed by tryptophan can be passed to the terbium, which the terbium then emits at a different wavelength," said Cotruvo. "The green color of this emission is actually one of the main reasons terbium is used in technologies like smart phone displays. For our purposes, when the tryptophan-lanmodulin compound binds to terbium, we can observe the emitted light, or luminescence, to measure the concentration of terbium in the sample."

The researchers developed many variants of the tryptophan-lanmodulin sensor, optimizing the location of the tryptophan so that it does not interfere with lanmodulin's ability to bind to rare earth elements. These variants provided important insights into the key features of the protein that enable it to bind rare earths with such high selectivity. Then, they tested the most promising variant to determine the lowest concentration of terbium the sensor could detect in idealized conditions—with no other metals to interfere. Even under highly [acidic conditions](#), like that found in acid mine drainage, the sensor could detect environmentally relevant levels of terbium. "One challenge with extracting rare earth elements is that you have to get them out of the rock," said Cotruvo. "With acid mine drainage, nature has already done that for us, but looking for the rare earths is like finding a needle in a haystack. We have existing infrastructure to treat acid mine drainage sites at both active and inactive mines to mitigate their environmental impact. If we can identify the sites with the most valuable rare earth elements using [sensors](#), we can better focus extraction efforts to turn waste streams into revenue sources."

Next, the researchers tested the sensor in actual samples from an acid mine drainage treatment facility in Pennsylvania, an acidic sample with

many other metals present and very low levels of terbium—3 parts per billion. The sensor determined a concentration of terbium in the sample that was comparable what they detected with the "gold standard" method, suggesting that the new sensor is a viable way to detect low concentrations of [terbium](#) in complex [environmental samples](#).

"We plan to further optimize the sensor so that it is even more sensitive and can be used more easily," said Cotruvo. "We also hope to target other specific rare [earth](#) elements with this approach."

More information: Emily R. Featherston et al, Probing Lanmodulin's Lanthanide Recognition via Sensitized Luminescence Yields a Platform for Quantification of Terbium in Acid Mine Drainage, *Journal of the American Chemical Society* (2021). [DOI: 10.1021/jacs.1c06360](https://doi.org/10.1021/jacs.1c06360)

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