Magnets sustainably separate mixtures of rare earth metals

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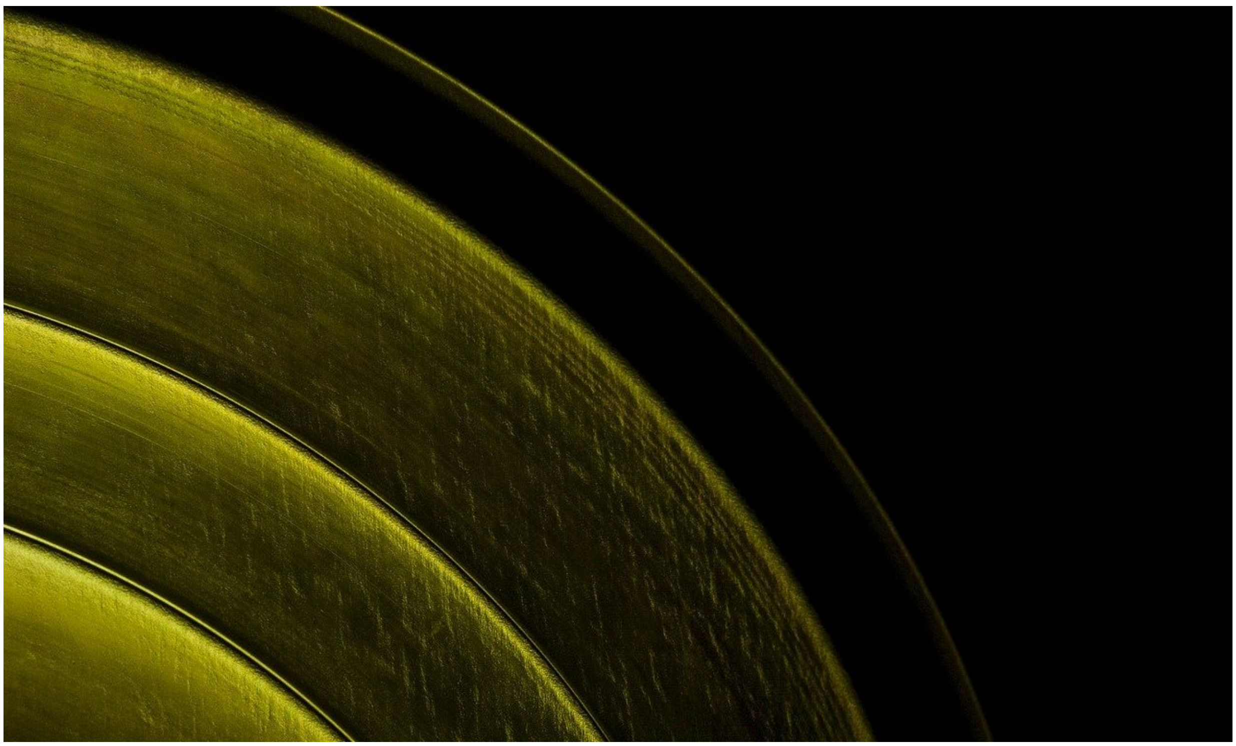

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A new study describes a novel approach for purifying rare earth metals, crucial components of technology that require environmentally-damaging mining procedures. By relying on the metal's magnetic fields during the crystallization process, researchers were able to efficiently and selectively separate mixtures of rare earth metals.

Seventy-five of the periodic table's 118 elements are carried in the pockets and purses of more than 100 million U.S. iPhone users every day. Some of these elements are abundant, like silicon in computer chips or aluminum for cases, but certain metals that are required for crisp displays and clear sounds are difficult to obtain. Seventeen elements known as rare earth metals are crucial components of many technologies but are not found in concentrated deposits, and, because they are more dispersed, require toxic and environmentally-damaging procedures to extract.

With the goal of developing better ways to recycle these metals, new research from the lab of Eric Schelter describes a new approach for separating mixtures of rare earth metals with the help of a magnetic field . The approach, published in *Angewandte Chemie International Edition*, saw a doubling in separation performance and is a starting point towards a cleaner and more circular rare earth metals economy.

The standard approach for separating mixtures of elements is to perform a chemical reaction that causes one of the elements to change phase, like going from liquid to solid, which allows elements to be separated using physical methods like filtration. This type of approach is used to separate rare earth metals; mixtures are placed into a solution of an acid, and an organic compound and individual metal ions slowly move out of the acidic phase and into the organic phase at varying rates based on the metal's chemical properties.

What's difficult is that many chemical properties, such as solubility or how they react with other elements, are very similar between rare earth metals. This lack of a strong chemical difference means that separating rare earth metals is a time and energy-consuming process that also generates a substantial amount of acid waste. "It works well when you do it 10,000 times, but each individual step is poorly efficient," says Schelter.

Where individual rare earth metals do differ is their paramagnetism, or how attracted they are to magnetic fields. Researchers have been interested in finding ways to use paramagnetism to isolate different rare earth elements, but previous efforts hadn't found ways to couple paramagnetism with a chemical reaction or phase shift.

The key discovery was that combining a magnetic field with a decrease in temperature caused metal ions to crystallize at different rates. Crystallizing elements by decreasing temperature is a commonly used approach in the lab, but the magnitude of its impact was unexpected. "We use lower temperatures to crystallize a lot of our materials," explains postdoctoral researcher Robert Higgins, who led the study. "It was one of the things I could potentially use, but didn't realize at the beginning how important that was actually going to be."

Using this approach, researchers can efficiently and selectively separate heavy rare earths like terbium and ytterbium from lighter metals such as lanthanum and neodymium. The most striking result was taking a 50/50 mixture of lanthanum and dysprosium and getting back 99.7% dysprosium in one step—a "100% boost" compared to the same method but without using a magnet.

Since the chemical mechanisms of existing separation approaches aren't well understood, researchers hope that their systematic approach can take metals separation technologies from "magic" to something more controllable, competitive, and cost effective. "If you could rationally design ways to improve metals separation, that would be a huge advantage," says Schelter. "Our position is to address niche applications related to chemical separations using an approach that can be applied to new separation systems to complement existing technology."

Higgins is now looking for ways to improve the reaction's efficiency while studying how magnetic fields interact with these chemical solutions. He sees this study and other fundamental chemistry findings as an important first step towards making rare earth metal recycling more efficient and sustainable. "The faster we can find new ways of performing separations more efficiently, the faster we can improve some of the geopolitical and climate issues that are associated with rare earth mining and recycling," says Higgins.

More information: Robert F. Higgins et al, Magnetic Field Directed Rare-Earth Separations, *Angewandte Chemie International Edition* (2019). DOI: 10.1002/anie.201911606

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