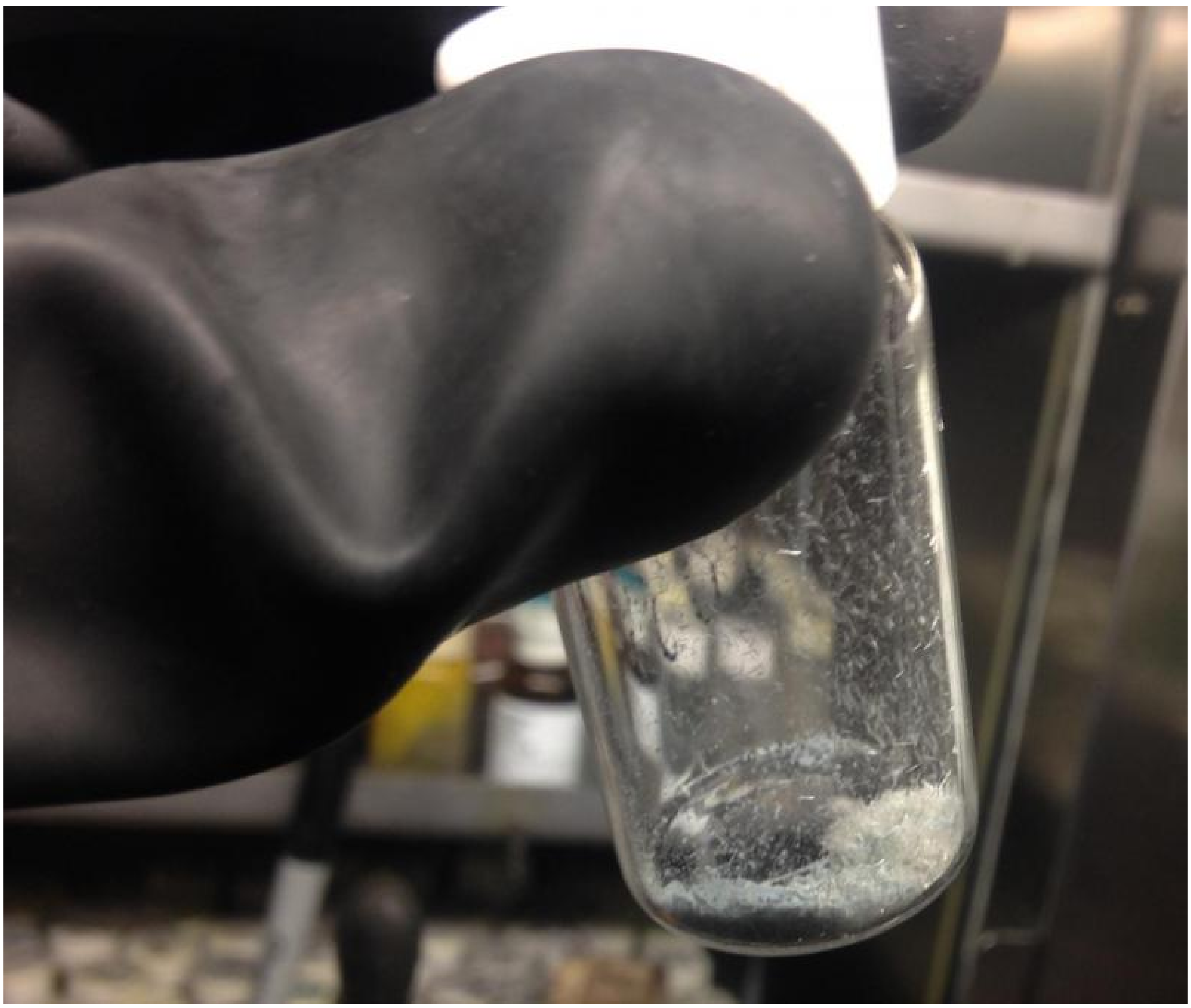
Research simplifies recycling of rare-earth magnets

June 18 2015



Starting with neodymium and dysprosium as a mixed powder, a metal-binding molecule known as a ligand is applied. Credit: University of Pennsylvania

Despite their ubiquity in consumer electronics, rare-earth metals are, as their name suggests, hard to come by. Mining and purifying them is an expensive, labor-intensive and ecologically devastating process.

Researchers at the University of Pennsylvania have now pioneered a process that could enable the efficient recycling of two of these metals, neodymium and dysprosium. These elements comprise the small, powerful magnets that are found in many high-tech devices.

In contrast to the massive and energy-intensive industrial process currently used to separate rare earths, the Penn team's method works nearly instantaneously at room temperature and uses standard laboratory equipment.

Sourcing neodymium and dysprosium from used electronics rather than the ground would increase their supply at a fraction of the financial, human and environment cost.

The research was lead by Eric J. Schelter, assistant professor in the Department of Chemistry in Penn's School of Arts & Sciences, and graduate student Justin Bogart. Connor A. Lippincott, an undergraduate student in the Vagelos Integrated Program in Energy Research, and Patrick J. Carroll, director of the University of Pennsylvania X-Ray Crystallography Facility, also contributed to the study.

It was published in *Angewandte Chemie International Edition*.

"Neodymium magnets can't be beat in terms of their properties," Schelter said. "They give you the strongest amount of magnetism for the smallest amount of stuff and can perform at a range of temperatures."

These thermal qualities are achieved by mixing neodymium with other elements, including the rare-earth metal dysprosium, in different ratios.

Because those ratios differ based on the application the magnet is being used for, the two metals need to be separated and remixed before they can be reused.

Size differences between the neodymium and dysprosium ions mean that ligand-neodymium complexes bind with one another, while their dysprosium counterparts do not. Credit: University of Pennsylvania

"It's, in principle, easier to get the neodymium and dysprosium out of technology than it is to go back and mine more of the minerals they are originally found in," Schelter said. "Those minerals have five elements to separate, whereas the neodymium magnet in a wind turbine generator only has two."

Currently, whether purifying the neodymium and dysprosium out of minerals or out of an old power tool motor, the same costly and energy-intensive process is used. The technique, known as liquid-liquid extraction, involves dissolving the composite material and chemically filtering the elements apart. The process is repeated thousands of times to get useful purities of the rare-earth metals, and so it must be conducted on an industrial scale.

Rather than this liquid-liquid method, Schelter's team has devised a way to separate the two metals.

"When we started," Bogart said, "our goal was to make rare earth separations simpler and more efficient and we have made strides towards just that. We have designed a way to separate the two metals by selectively dissolving the neodymium in a solution and leaving behind the dysprosium as a solid. This quick and easy method has allowed us to separate equal mixtures of the metals into samples that are 95 percent pure."

Their method can, in a matter of minutes, separate an equal mixture of the two elements into samples that are 95 percent pure.

Starting with the two elements as a mixed powder, a metal-binding molecule known as a ligand is applied. The type of ligand the research team designed has three branches, which converge on the metal atoms and hold them in the aperture between their tips. Because of neodymium's slightly larger size, the tips don't get as close together as they do around dysprosium atoms.

Because neodymium-ligand complexes bind together into dimers, their solubility is higher than the dysprosium-ligand monomers. This allows the former to be easily filtered off. Credit: University of Pennsylvania

"The difference in size between the two ions is not that significant, which is why this separation problem is difficult," Schelter said, "But it's enough to cause that aperture to open up more for neodymium. And, because it is more open, one ligand-neodymium complex can combine with another, and that really changes its solubility."

The combination of the two neodymium complexes, known as a dimer, encapsulates the neodymium ions, enabling them to dissolve in solvents like benzene or toluene. The dysprosium complexes do not dissolve, enabling the two metals to be easily separated. Once apart, an acid bath can strip the ligand off both metals, enabling it to be recycled as well.

"If you have the right ligand, you can do this separation in five minutes, whereas the liquid-liquid extraction method takes weeks," Schelter said. "A potential magnet recycler probably doesn't have the capital to invest in an entire liquid-liquid separations plant, so having a chemical technology that can instantaneously separate these elements enables smaller scale recyclers to get value out of their materials."

Future work will involve improving the stability of the ligand so it is less likely to fall off before the metals are separated.

"These results are encouraging," Bogart said. "We feel that through slight adjustments to the system, the purity level could be increased even further."

Further modification of the ligand could enable other rare earths in technology products, such as compact fluorescent light bulbs, to be recycled this way.

More information: *Angewandte Chemie International*

*Edition*dx.doi.org/10.1002/anie.201501659

Provided by University of Pennsylvania

Citation: Research simplifies recycling of rare-earth magnets (2015, June 18) retrieved 28 April 2024 from https://phys.org/news/2015-06-recycling-rare-earth-magnets.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.