Center for Energy Initiatives
An AIChE Technological Community
Derrick Wu

A Critical Problem to Solve

We treat our phones as necessary extensions of ourselves, and it is now hard to imagine life without what has become like an additional limb. Similarly, we have grown so used to computers, cars, and items requiring batteries that many of us would describe them as critical to our everyday lives. Besides our attachment to them, what do all of these items have in common? They all include what are dubbed critical materials.

Critical materials are elements, often rare-earth elements (REEs), that are produced in limited quantities, but for which demand is high, putting the supply at risk for disruption. While the classification for criticality varies throughout the world, elements that are often categorized as critical include indium, scandium, dysprosium, neodymium, yttrium, and gallium. The production of many of these elements is less than thousands of tons per year. Yet, these materials are essential to green technologies, such as wind turbines and solar cells, as well as technologies like computer chips and screens, smartphones, fluorescent lights, rechargeable batteries, electric vehicles, healthcare devices, and chemical catalysts.

As more and more uses for critical materials are developed, the U.S. Geological Survey (USGS) estimates that the global demand for REEs will increase by more than 5% per year through 2020. Agencies and organizations such as the U.S. Dept. of Energy (DOE) and the European Union (EU) have expressed concern about the lack of supply of these materials, and world leaders agree that resource efficiency is paramount.

Strategies are in place to improve the accessibility of critical materials. Government programs aim to reduce reliance on them, and researchers are searching for feasible substitutes as well as improved methods of separating, extracting, and recycling REEs.

One such program is the Critical Materials Institute (CMI), which is a group of DOE national laboratories, universities, and industrial partners that work together to eliminate materials criticality as an impediment to the commercialization of clean energy technologies.

Recently, the DOE and Pennsylvania State Univ. (PSU) teamed up to develop a better method for separating REEs from coal. They found that rinsing coal with a solution to unbind the REEs is more efficient than existing methods of removing REEs from coal. The ion exchange technique can be used to extract REEs from discarded coal byproducts, enabling coal-production companies to reuse and reduce waste. This could be a major breakthrough, as separating REEs with current technologies and methods is challenging.

In fact, rare earth elements are not even very rare — they can be found in widely distributed mineral deposits — but the costs and challenges, including high energy costs, the need to use concentrated acids, mining regulations, lack of developed supply lines, and other restrictions, inhibit production and limit availability. For example, the DOE/PSU team believes that even extracting just 2% of the available REEs would provide an economic boon. Researching ion exchange and other separation techniques could help increase production of critical materials.

In addition to finding ways to ramp up production of critical materials, researchers are searching for substitutions and recycling methods. A Yale research team attempted to find substitutes for 62 elements, but did not find suitable materials that serve the same function (using a weak substitute can inhibit equipment performance). For example, air conditioners that employ a rare-earth magnet motor are significantly more efficient than those without these magnets. The Yale research team's findings expose the opportunity for scientists and engineers to develop novel substitution methods.

The availability of critical materials could be enhanced if more were recycled and reused. According to the CMI, only 1% of critical materials are recycled at the end of a product's life cycle. Recycling could be increased if products were designed to be easier to recycle, recycling techniques were improved, and awareness of the importance of recycling critical materials were encouraged.

Research and technical gaps related to critical materials remain. To help fill those gaps, AIChE and its Center for Energy Initiatives (CEI), with support from the National Science Foundation (NSF), have hosted various events, including the Ensuring the Sustainability of Critical Materials and Alternatives workshop (Philadelphia, PA, 2012) and the Separation Science and Technology as a Convergence Platform for SusChEM (Sustainable Chemistry, Engineering, and Materials) workshop (San Francisco, CA, 2014). These meetings included speakers and discussions focused on the need to advance critical materials research. One key point that stood out was the call to include more education on separation sciences in the undergraduate chemical engineering curriculum, with the goal of encouraging more engineers to research and develop critical materials solutions. AIChE hopes to help
by supporting additional activities and services to improve critical materials research. If you want to get involved, please contact energy@aiche.org. CEP