New device could help scientists design new fuel reprocessing methods

October 20 2011, By Louise Lerner

Argonne scientists Artem Guelis (right) and Kevin Nichols test their miniaturized apparatus for nuclear recycling research.

Designing better ways to recycle spent nuclear fuel could make nuclear energy a safer solution to the global energy problem, but there are a lot of gaps in our chemical knowledge -- and it's difficult to get those answers when the experiments involve radioactive material.

Scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory have one answer: Shrink the whole experiment down—to microliters.

When it comes out of a reactor, nuclear spent fuel contains a whole glut of different radioactive isotopes, all mixed together.

For years, scientists have looked for ways to separate out reusable fuel from the truly toxic stuff.

The nations that recycle spent nuclear fuel today use processes based on PUREX, a technique whose underpinnings date back to the 1940s. Ideally, new processes would make fuel recycling cheaper, safer and less complex.

But one big challenge to creating models that accurately represent fuel reprocessing lies in determining the rates of reaction in the procedure—essentially, how quickly different elements move between phases.

Recycling nuclear fuel is fundamentally a sorting exercise: chemists want to sift out the useful uranium from the bulk of other byproducts and highly radioactive ones. The fuel is dissolved in acid and different metals can be separated out using solvent extraction—a bit like oil collecting on the surface of a bottle of salad dressing. The rates at which the metals separate is determined by kinetics, and knowing the rates helps scientists design new and better techniques.

"From the chemistry standpoint, if we want to be able to design new and improved nuclear recycling schemes, you have to be able to understand the mechanism," said Argonne chemical engineer Kevin Nichols, who helped lead the research. "You have to be able to develop chemical insight, which comes from knowing the kinetics."

Previous experiments that looked into the kinetics of these particular classes of reactions used large volumes of material, which slows the process and leads to less accurate results. But Nichols and chemist Artem Gelis have built a solution: an apparatus that miniaturizes the process.

"If we cut the size down, we can do the same experiment much more quickly, generate less waste and get more precise measurements," Gelis explained.

The apparatus uses mere drops of radioactive material, rather than liters. This allows hundreds or even thousands of trials to be performed with just a few microliters of sample.

The new process grew out of a combination of solvent extraction research being done at Argonne and work being done by University of Chicago professor Rustem Ismagilov, whose laboratory created a miniaturized apparatus for protein crystallization. The process generated thousands of aqueous droplets containing proteins separated by an oil layer, which—as it happens—is similar to the process for nuclear recycling. Though it had not been tried before, the researchers decided to modify the technique for nuclear fuel treatment kinetics.

Next, the team is planning to adapt the technique for other applications, such as processes that produce radioactive isotopes for medical use or even rare earth metal processing.

Rare earth metals are used in many energy technologies, such as solar panels and compact fluorescent lightbulbs, but today are primarily mined in China. The U.S. has rare earth metal deposits, but the popularity of renewable energy has triggered new interest in making U.S. rare earth metal mining more economical.

More information: The paper, "Toward Mechanistic Understanding of Nuclear Reprocessing Chemistries by Quantifying Lanthanide Solvent

Extraction Kinetics via Microfluidics with Constant Interfacial Area and Rapid Mixing", was published in the *Journal of the American Chemical Society* and is available online.

Provided by Argonne National Laboratory