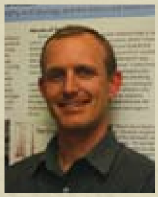
A Positive Exchange

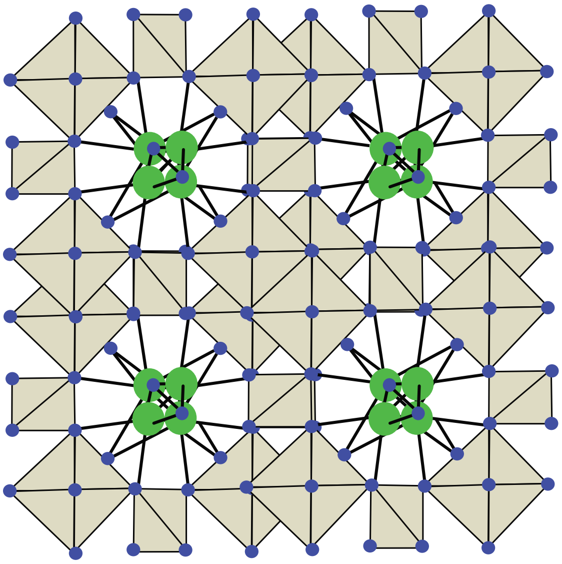
BY MOLLY SWIETEK



Dr. Aaron Celestian

NINETY MILES NORTHWEST OF LAS VEGAS SITS YUCCA MOUNTAIN, A VOLCANIC RIDGE PROPOSED AS THE SITE FOR THE NATION'S NUCLEAR WASTE REPOSITORY. POTENTIALLY — PENDING A FINAL DECISION BY THE GOVERNMENT — TONS OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE MAY BE TRANSPORTED THERE FROM OVER 120 CURRENT STORAGE SITES FROM ALL ACROSS THE COUNTRY. TRANSPORTING AND STORING SUCH HIGHLY RADIOACTIVE MATERIAL HAS ITS DANGERS, BUT DR. AARON J. CELESTIAN, AN ASSISTANT PROFESSOR IN THE DEPARTMENT OF GEOLOGY AND GEOGRAPHY AT WESTERN KENTUCKY UNIVERSITY, IS WORKING TO MAKE SURE WHAT HAPPENS IN YUCCA MOUNTAIN STAYS IN YUCCA MOUNTAIN — SAFELY.

Celestian's research focuses on engineering crystalline materials to selectively separate high-level radioactive waste into an environmentally stable form. The process is known as ion exchange. Celestian, along with his team of graduate and undergraduate researchers, is working to develop a material that will selectively target and sequester radioactive ions, such as cesium and strontium. Both elements occur naturally in the environment but become unstable and toxic through nuclear fission. Nuclear power plants producing atomic energy and weapons generate large quantities of radioactive cesium and strontium. "Currently, thirty-nine states have radioactive material storage sites," said Dr. Celestian. "There is an abundance of radioactive waste contaminants, and the question is, 'What do we do with it?'" Celestian believes the answer is sequestration, or "locking up" the radioactive elements so they can be safely transported and put into long-term storage with other environmentally hazardous materials. According to Celestian, "We're researching ways to permanently isolate unstable ions, such as cesium, and to reduce the negative environmental and health impacts of radioactive waste."



Synthetic Sitinakite — Radioactive Ions

A specimen of stilbite and apophylite: typical, naturally occuring zeolites

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To achieve such a feat, Dr. Celestian studies ion exchange in synthetic sitinakite, a porous structure known for its very high ion selectivity. Sitinakite possesses characteristics similar to naturally occurring zeolites and clays — minerals with the molecular ability to remove positively-charged ions known as cations. "By examining naturally occurring selectivity, we can begin to understand how nature fine-tunes structure for functionality," said Celestian. "Observing such a phenomenon provides hope that biological-like functionality, in terms of ion selectivity, might be possible in other synthetic materials."

Understanding the natural functions of minerals in the earth is the first step toward engineering artificial materials manufactured for a specific function, like sequestering radioactive contaminants. Zeolites are used for many practical day-to-day purposes, such as absorbing ammonium in cat litter, replacing calcium with sodium to soften water, and refining oil to generate gasoline. Another example of natural ion exchange can be found in the use of clay to sequester toxins from contaminated soil. Clay minerals are porous materials that are mechanically capable of exchanging ions. However, clay is not a highly selective mineral, nor does it "lock in" ions. By examining how ions move in and out of a crystal structure, such as clay, scientists like Aaron Celestian can begin engineering efforts to design a crystalline structure capable of targeting and encapsulating specific ions. "We want to know exactly how minerals behave in the environment and how they react to toxins," he said. "By understanding the principal atomistic mechanisms responsible for a material's functionality, we are able to establish methodologies to modify its properties to develop enhanced synthetic materials for ion separation technologies in waste remediation."

Dr. Celestian's interests in ion exchange processes developed from his early studies in mineralogy. After earning his bachelor's degree from the University of Arizona, he continued his academic pursuits at Stony Brook University, where he earned his master's degree in 2002 and a doctorate in geosciences in 2006. Following his faculty appointment at WKU in 2007, Celestian immediately began engaging his students in researching the ion exchange process in crystalline structures. "I really enjoy teaching in the classroom and get a lot of satisfaction from working directly with students in the lab," he said. "The research I enjoy doing directly supports the training and experimental studies of these students." Celestian's collaborative efforts with his students have resulted in the development of the Celestian Group, a team comprised of WKU graduate and undergraduate researchers. Experiments conducted by Celestian and Samantha Kramer, a graduate student studying geosciences, led to

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a joint presentation at the American Geophysical Union's 2008 meeting.

In WKU's Crystal Kinetics Laboratory and Materials Characterization Center, the Celestian Group is currently working to develop synthetic ion exchangers. The group focuses their research efforts on engineering crystalline silicotitanates (CST), a nanoporous material designed for the targeted removal of cesium. According to the group's website *(www.wku.edu/~aaron.celestian/)*, "combining information from time-resolved X-ray and neutron scattering with theoretical calculations reveals the elegant mechanism whereby CST achieve their remarkable ion exchange selectivity from cesium."

Due to the speed at which ion diffusion takes place, it is difficult to view the complex structure of crystalline materials and to study the exact process of ion exchange in real-time. X-ray diffraction and neutron scattering techniques provide relevant information needed to determine the characteristics of ion mobility and pathways of exchange. Only national laboratories are capable of monitoring chemical reactions fast enough to provide real-time observation of the ion exchange process. With grant funds provided by a WKU-sponsored Faculty Scholarship Award, Celestian and several students were able to travel to the National Synchrotron Light Source laboratory in Brookhaven, New York, to initiate experiments on the exchange process between the element strontium and the CST materials engineered by the Celestian Group.

The initial results of the experiments showed how strontium migrated into the synthetic sitinakites, and how the crystal structures expanded to accommodate the selected ions. The broader results, however, indicate this preliminary data will serve as a stepping stone to developing more exploratory benefits of selective ion exchange. "With greater knowledge of the exchange mechanisms, we can more accurately develop new materials with an eye toward permanent sequestration of selective ions," said Celestian. Future applications of synthetic ion exchangers could include preventing viruses from penetrating cells and also lead to the development of more effective anti-viral drugs. In the case of radioactive contaminants, as concern grows over the environmental and health impacts of nuclear waste, the real-world applications of Celestian's research are more timely and relevant than ever. "We could potentially discover a way to permanently sequester radioactive elements and prevent them from entering the environment," he said.

The knowledge gained from the research on ion exchange has far-reaching implications, yet it appears the most positive exchange occurs in the lab between Celestian and his students who are active participants in his highly important work. "I hope to provide my students with scientifically enriching experiences and collaborative development," said Celestian. "I enjoy giving them the opportunity to travel and work in world-renowned research laboratories. Our studies address a number of real-world problems, from healthcare concerns to environmental issues, and it's exciting to think about the possible impact we could have on a global scale."