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By: Lucian Dorneanu, Science Editor

Plutonium Nuclear Bomb Explosion

Unusual Properties of Plutonium

New theory about its ever-shifting face

Plutonium is a radioactive, metallic chemical element, and has been called "the most complex metal" and “a physicist's dream but an engineer's nightmare” for its peculiar physical and chemical properties.

It is the element used in most modern nuclear weapons and power plants, and contrary to popular beliefs propagated by the movie industry, it does not glow green.

However, while the complex nuclear characteristics of plutonium are well-known, it has properties as a metal or a chemical compound that have often left scientists scratching their heads.

Researchers at Rutgers, The State University of New Jersey, have unlocked some of its the physical and chemical secrets, and report that the valence electrons – those which control how atoms bond with each other – fluctuate among different orbitals in solid plutonium metal on a very short time scale.

Plutonium's eight outermost or "valence" electrons can circulate among different orbitals, or regions around the atom. In plutonium's 5f orbital, the one with the greatest influence on its atomic properties, the number of valence electrons it contains is most often five (approximately 80% of the time), but can also be six (about 20% of the time) or four (less than 1% of the time), according to the theory. These electrons shuttle in and out of the 5f orbital very quickly—in a matter of femtoseconds, or quadrillionths of a second, the researchers say.

"Previous theories about plutonium’s makeup placed a fixed number of valence electrons in the particular orbital we examined, known as the 5f orbital," said Kristjan Haule, an assistant professor of physics and astronomy at Rutgers. "Different theories assigned different numbers of electrons to that orbital – some four, others five and yet others, six. But whatever number the theory prescribed, it remained constant. Each theory could explain some of the element’s characteristics, but none could account for all the experimental evidence."

As their analysis shows, the 5f orbital dictates many of plutonium's key properties, such as its lack of conductivity and net magnetism. With their theory, the researchers have also explained the magnetic and electrical properties of americium and curium.

The reported findings strengthen methods for predicting characteristics of all of these complex materials and they hope their approach will also elucidate the properties of rare-earth elements on the periodic table.