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The Ever-Shifting Face of Plutonium

A new theory explains some of the unusual properties of plutonium, the radioactive metal best known for its proclivity to undergo nuclear fission chain reactions, making it a potent fuel for nuclear weapons and power plants. Plutonium is one of the most unusual metals--it's not magnetic and it does not conduct electricity well. The material also changes its size dramatically with even the slightest changes in its temperature and pressure. The atom's unusual set of properties distinguishes it from even its closest neighbors on the periodic table, such as americium.

What makes plutonium unique? In the new theory, developed by condensed-matter theorists at Rutgers University in New Jersey, 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--on the order of femtoseconds, or quadrillionths of a second, the researchers say.

Plutonium is an example of a strongly correlated material, in which the valence electrons interact with each other to a great degree, and cannot be treated as independent agents. Taking these interactions into account, the researchers combined two theoretical approaches to solid materials, called the local density approximation and dynamical mean field theory, to come up with their sophisticated analysis.

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. They hope their approach will also elucidate the properties of rare-earth elements on the periodic table (Shim *et al.*, **Nature** (http://www.nature.com/index.html) , 28 March 2007.)

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