Weak atomic bond, theorized 14 years ago, observed for first time

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A Purdue University physicist has observed a butterfly Rydberg molecule, a weak pairing of two highly excitable atoms that he predicted would exist more than a decade ago.

Rydberg molecules are formed when an electron is kicked far from an atom's nucleus. Chris Greene, Purdue's Albert Overhauser Distinguished Professor of Physics and Astronomy, along with his co-authors H. Sadeghpour and E. Hamilton, theorized in 2002 that such a molecule could attract and bind to another atom.

"For all normal atoms, the electrons are always just one or two angstroms away from the nucleus, but in these Rydberg atoms you can get them 100 or 1,000 times farther away," Greene said. "Following preliminary work in the late 1980s and early 1990s, we saw in 2002 the possibility that this distant Rydberg electron could bind the atom to another atom at a very large distance. This electron is like a sheepdog. Every time it whizzes past another atom, this Rydberg atom adds a little attraction and nudges it toward one spot until it captures and binds the two atoms together."

A collaboration involving Greene and his postdoctoral associate Jesus Perez-Rios at Purdue and researchers at the University of Kaiserslautern in Germany has now proven the existence of the butterfly Rydberg molecule, so named for the shape of its electron cloud. Their findings were published in the journal *Nature Communications*.

"This new binding mechanism, in which an electron can grab and trap an atom, is really new from the point of view of chemistry. It's a whole new way an atom can be bound by another atom," Greene said.

The researchers cooled Rubidium gas to a temperature of 100 nano-Kelvin, about one ten-millionth of a degree above absolute zero. Using a laser, they were able to push an electron from its nucleus, creating a Rydberg atom, and then watch it.

"Whenever another atom happens to be at about the right distance, you can adjust the laser frequency to capture that group of atoms that are at a very clear internuclear separation that is predicted by our theoretical treatment," Greene said.

They were able to detect the energy of binding between the two atoms based on changes in the frequency of light that the Rydberg molecule absorbed.

Greene said it's satisfying to know that the predictions made so long ago have been proven.

"It's a really clear demonstration that this class of molecules exist," Greene said. "It also validates the whole theoretical approach that we and a few other groups have taken that led to the prediction and study of this new class of molecules.

"These molecules have huge electric dipole moments which allow them to be manipulated by weak electric fields 100 times smaller than those needed to move common diatomic molecules; this could one day be applied to the development of molecular scale electronics or machines."

Greene will continue to study Rydberg atoms, including tests to see if multiple atoms could be bound to a Rydberg molecule.

More information: Observation of pendular butterfly Rydberg molecules, *Nature Communications*, 2016.

Provided by Purdue University

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