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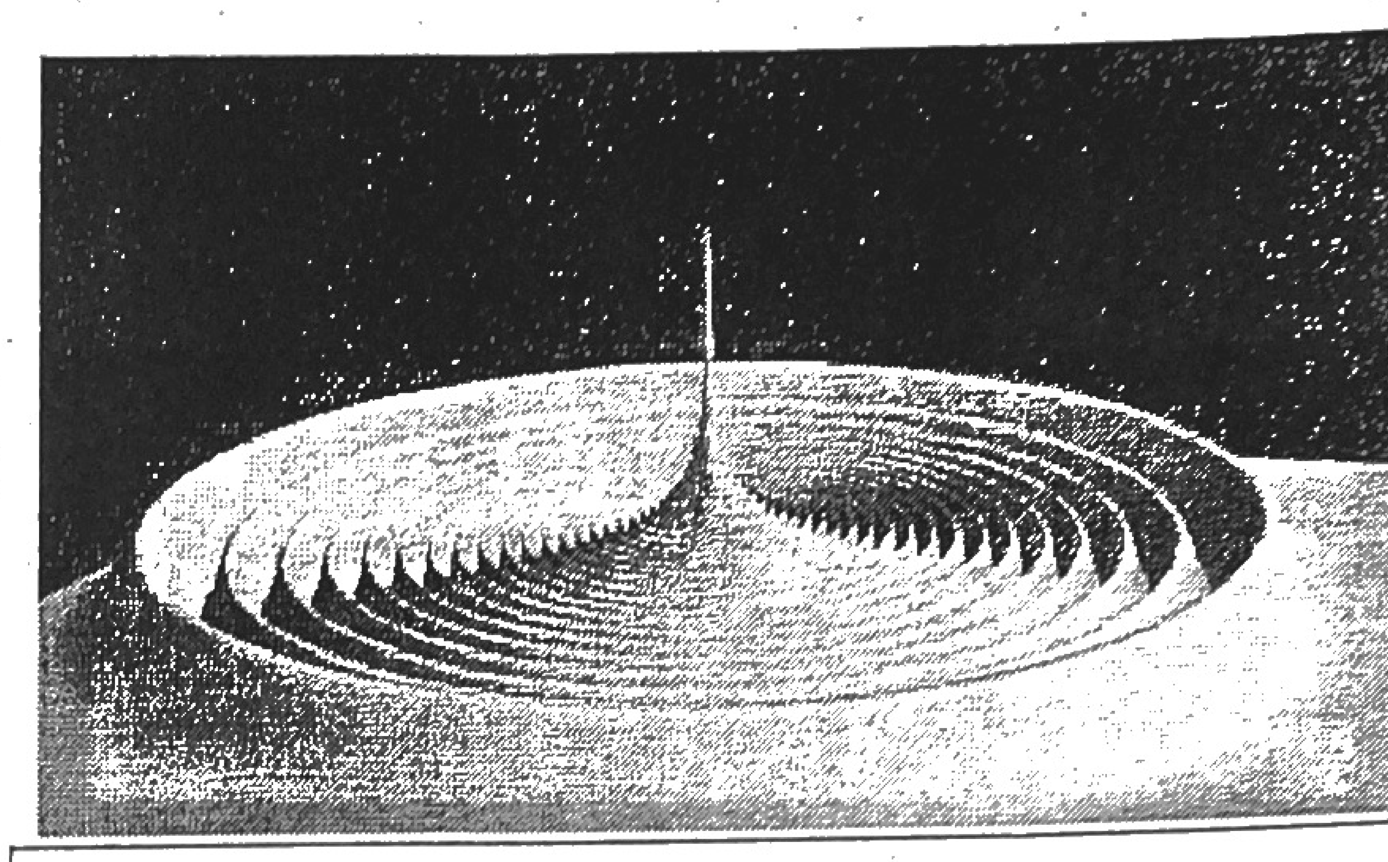
A New Type of Chemical Bond Takes Hold

By Adrian Cho Apr. 23, 2009 , 12:00 AM



Way out. This plot shows the probability for finding the electron at a different distance from the nucleus in a highly excited state of rubidium. In the molecule, the unexcited atom gets stuck in one of the outer rings.

Vera Bendkowsky/University of Stuttgart

For decades, scientists have known of three ways for two atoms to bind and form a molecule. Now, researchers have discovered a fourth. Most likely, the advance won't lead to new materials or technologies: The molecules last for about 1/100,000 of a second and can be made only at temperatures a few millionths of a degree above absolute zero. However, their mere existence confirms a surprising prediction and stretches the conceptual boundaries of chemistry.

There aren't many ways to bind two atoms. In the first two strategies, two atoms bind when their orbitals--the cloudlike distributions of electrons that hover above the atomic nucleus--overlap and merge so that the atoms share one or more electrons. If the atoms are of the same element, they will share an electron equally, producing a so-called covalent bond. If the atoms are of different elements--say sodium and chlorine--then one may hog the shared electron in what's called an ionic bond. In a third type of bond, called a van der Waals bond, the atoms don't actually share their electrons; instead, tiny fluctuations make one atom momentarily more positively charged on one side than on the other. This fleeting "polarization" induces similar fluctuations in the other atom, pulling the two atoms together.

Vera Bendkowsky, Tilman Pfau, and colleagues at the University of Stuttgart in Germany have demonstrated a fourth way to bind two atoms. The researchers started out with a gas of ultracold rubidium atoms. Using a carefully tuned laser, they then "excited" an electron in some of the atoms to a very high-energy orbital. That orbital is so large that the electron hovers as much as 100 nanometers from the nucleus, which is about 400 times the radius of a normal rubidium atom. If another, unexcited rubidium atom happens to be about that close, it can bind to the excited one, settling into the outer reaches of the electron cloud to make a gigantic two-atom molecule that's bigger than some viruses.

That's because the far-flung electron in the excited atom collides with the unexcited atom over and over again, tugging on it very slightly each time. In fact, thanks to quantum uncertainty, the electron is essentially everywhere in its orbital at the same time, so it is constantly bouncing off the unexcited atom. This "scattering" amounts to a gentle nudging that keeps the unexcited atom from wandering away. It creates a very weak bond that lasts roughly until the excited atom loses its extra energy, the researchers report today in *Nature*. As the two rubidium atoms neither share an orbital nor polarize each other, the interaction constitutes a whole new type of chemical binding.

The existence of such molecules had been predicted in 2000 by a team led by Chris Greene, a theorist at JILA, a laboratory run jointly by the National Institute of Standards and Technology and the University of Colorado, Boulder. "It's pretty nice to have a confirmation and to know that people will take your [theoretical] approach maybe even more seriously," Greene says. Molecules with weird shapes might also be made by exciting the atoms in slightly more complicated ways. But Bendkowsky notes: "I can't tell you of any applications where you might build something out of these molecules. This is just fundamental physics."

A New Type of Chemical Bond Takes Hold – Reading Questions

1. List the three common types of bonds and describe each one:

2. Researchers used a carefully tuned laser to do what?

3. Are high energy orbitals located close to the nucleus or far away from the nucleus? Why?

4. What happens to the excited electron that causes a bond to form?

5. Is this type of bond strong or weak?