Researchers devise a means to control chemical reactions in individual atoms

July 25 2012, by Bob Yirka

(Phys.org) -- In the early days of chemistry, finding out what happened when two or more chemicals were mixed together led to the development of all manner of new materials and to deriving useful events, such as the production of heat or light, or things exploding. As the science progressed however, researchers found they wanted to know more about what really goes on when chemicals react, but were unable to find out due to the massive number of interactions that occur during even the most ordinary chemical reactions. Nowadays, researchers want to delve even deeper, to discover what goes on at the quantum level. To that end, a team working at the Cavendish laboratory in Cambridge, UK has developed a way to monitor and control one of the most basic chemical reactions, the meeting of two dissimilar individual atoms. In their paper published in *Nature Physics* they describe how they were able to do so by setting up special experiments in a cold environment using a laser.

Under normal conditions, when two atoms meet, usually nothing happens. There is no attraction force between the two thus no reason for them to interact. When one or both are ions, things are different of course as the ions have either more or less electrons than stable atoms, causing them to have an electric charge. It was this property that the team used when setting up their experiments, which were meant to serve as an observational study, not to create something new, to see what happens at the quantum level.

In their experiments, the team used a magnetic field to isolate two different types of atoms, a ytterbium ion and a neutral rubidium, in a very cold environment to slow things down. But prior to pushing them together with a laser, they first excited the ytterbium ion by shooting it with laser light to inject it, so to speak with kinetic energy. That energy they noted, could result in movement due to heat ejection or in the production of photons.

Next, they ran two different types of experiments. In the first, they turned off the lights and watched as the two atoms eventually came near one another, to see if the interaction between the two would result in the release of photons, i.e. light. It did not, instead, it resulted in both atoms moving around in the trap at higher speeds.

In the second experiment they used a laser to push the energized ion towards the neutral atom and found that in some, but not all cases, an ion was exchanged, causing the ytterbium atom to become neutral and the rubidium to become ionized; a clear example of a controlled chemical reaction between just two atoms. The researchers noted that the spin state of the atoms made a difference in the outcome of the reaction, meaning that the atomic nucleus of the atom had an impact, which goes counter to conventional thinking.

The experiments and results the researchers achieved show that chemical reactions can not only be studied at the quantum level, but controlled as well, a finding that will likely have a major impact on both chemistry and physics research going forward.

More information: Controlling chemical reactions of a single particle, *Nature Physics* (2012) doi:10.1038/nphys2373

Abstract

Traditionally, chemical reactions have been investigated by tuning thermodynamic parameters, such as temperature or pressure. More

recently, laser or magnetic field control methods have emerged to provide new experimental possibilities, in particular in the realm of cold collisions. The control of reaction pathways is also a critical component to implement molecular quantum information processing. For these studies, single particles provide a clean and well-controlled experimental system. Here, we report on the experimental tuning of the exchange reaction rates of a single trapped ion with ultracold neutral atoms by exerting control over both their quantum states. We observe the influence of the hyperfine interaction on chemical reaction rates and branching ratios, and monitor the kinematics of the reaction products. These investigations advance chemistry with single trapped particles towards achieving quantum-limited control of chemical reactions and indicate limits for buffer-gas cooling of single-ion clocks.

via Arstechnica

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