Matter and antimatter feel the chemistry

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"Antiprotonic hydrogen has already been produced," explains Nicola Zurlo, an investigator in the Chemistry and Physics Department, headed by professor Evandro Lodi-Rizzini, at the University of Brescia in Brescia, Italy. "But what we've done is produce it in a totally different way. The process and mechanism is completely different."

This new way of producing antiprotonic hydrogen, also called protonium, is set forth in a Letter published by Zurlo and his ATHENA collaboration colleagues on October 9 in *Physical Review Letters*. It is titled "Evidence For The Production Of Slow Antiprotonic Hydrogen In Vacuum."

The ATHENA (Apparatus for High precision Experiment on Neutral Antimatter) collaboration is a project associated with CERN in Geneva, Switzerland, comprising an international team including scientists from Italy, the United Kingdom, Japan, Switzerland, Denmark and Brazil. "We demonstrated more than a million antihydrogen atoms in our set of measurements," Zurlo tells *PhysOrg.com*. These antihydrogen atoms represent the simplest "chemical" structure made of antimatter, as atomic hydrogen is the simplest "chemical" structure in our usual "matter" world. Now, the work of the ATHENA collaboration has been focused on the production of the antiprotonic hydrogen by a chemical reaction between matter and antimatter. "This production was totally unexpected and increases by far the number of important results achieved in our work," says Zurlo.

Being able to generate protonium allows for experiments regarding binding energies, which are much higher than for the similar matter-only or antimatter-only systems, if protonium is in a near-fundamental state, even though there are "larger" protonium configurations with binding energies comparable to theirs. It will also be possible to devise more precise measurements allowing scientists to test natural laws, gaining a better understanding of them, in particular concerning the matter-antimatter symmetry and the CPT invariance. Even though the creation of protonium has been known before this, the inefficient method in which it was produced made it prohibitive in terms of doing experiments.

The ATHENA collaboration's new method allows a much more efficient way to use antiprotons and to produce protonium, explains Zurlo. Prior to this project, violent particle collisions between the antiprotons (produced by smashing a bunch of protons into a solid target) were needed: "Previously, there was a reaction only when an electron was kicked out," says Zurlo. Now, though, antiprotons — produced the same way as before — are decelerated through a process of cooling and slowing, and then are brought to a point where they can be trapped and then studied. Not only that, but also these antiprotons are used in the first "real" chemical reactions between matter and antimatter. "The range of the electric force between the antiprotons and the molecular hydrogen ions present in the center of our trap makes the reaction much more efficient," explains Zurlo.

Indeed, the reaction is efficient enough to create protonium that lasts much longer. "The mean lifetime is much longer than previously. It can allow us to make a spectroscopy, to find energy levels with improved accuracy, to form a new kind of test," enthuses Zurlo. Protonium decays rather rapidly, and this limits the amount of time for study. With the old method, the antiprotonic hydrogen annihilated itself in about one zillionth of a second. With the ATHENA collaboration's method, that time is extended to a millionth of a second — a vast improvement that makes study practicable.

Being able to cause chemical reactions between matter and antimatter can broaden our understanding of natural laws. With this result, says Zurlo, the ATHENA collaboration is breaking up to do further experiments, making new headway with the work started in Geneva. “There will be new experiments,” he says. “Now everything has changed.”

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