Physicists offer new approach to studying antimatter in the lab

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What happens when two atoms, each made up of an electron and its antimatter counterpart, called the positron, collide with each other? UC Riverside physicists are able to see for the first time in the laboratory that these atoms, which are called positronium atoms and are unstable by nature, become even more unstable after the collision. The positronium atoms are seen to destroy one another, turning into gamma radiation, a powerful type of electromagnetic radiation.

“Our research also gives the first hint of the presence of double positronium molecules, each of which is made up of two electrons and two positrons,” said Allen Mills, professor of physics and leader of the research project. “This kind of matter-antimatter pairing has never been formed or studied in the laboratory until now, and paves the way for a new field of study on its properties.”

The researchers will publish their work next month in *Physical Review Letters*.

Each particle of matter has a corresponding “antiparticle” of antimatter. Electrons are negatively charged particles that surround every atom's nucleus. The positron is an antiparticle with the same mass and magnitude of charge as an electron but exhibiting a positive charge. When matter, such as an electron, combines with an equal amount of antimatter, such as a positron, they are converted into energetic particles or radiation.

Positrons are generally short-lived because they tend to combine quickly with electrons. But, by storing the positrons in a “magnetic bottle,” physicists have been able to prolong the life of the positrons and accumulate millions of them at once.

In their experiments, the UCR researchers obtained positrons from a radioactive form of sodium. They emptied the positrons out of a magnetic bottle onto a small spot on a target surface comprised of a thin piece of porous silica. There, the positrons combined with electrons to spontaneously form a high concentration of unstable positronium atoms. The newly formed atoms quickly took up residence in the pores of the target, and began to collide with one another, producing energy in the form of gamma radiation.

“This is the first time anyone has been able to observe a collection of positronium atoms that collide with one another,” Mills said. “We knew we had a dense collection of these atoms because, being so close to one another, they were annihilating faster than when they were just by themselves.”

The research paves the way for future experiments that would use a positronium atom laser to search for anti-gravity effects associated with antimatter and to measure the properties of positronium to a very high precision.

“So far, we’ve had only a suggestion that double positronium molecules were present in our experiment,” Mills said. “Our next step will be to confirm their existence and to measure their properties.”

A brief history of antimatter and positronium

Antimatter is of intellectual interest to scientists because it represents a mirror universe in which gravity, for example, might work in the opposite direction, with things “falling up.”

Paul Dirac predicted antimatter in 1930. Carl Anderson discovered the positron in 1932. In 1946, John Wheeler predicted a series of matter-antimatter aggregations, which he called polyelectrons. Besides the electron and positron, Wheeler envisioned the existence of positronium, the positronium ion and the double positronium molecule. Positronium was discovered in 1951 in experiments by Martin Deutsch. Allen Mills produced positronium ions (two electrons and one positron) in 1981 at Bell Laboratories.

Positrons are of interest to plasma physicists, and also are used in studying the electronic structure of metals, for detecting defects in solids and for measuring the properties of surfaces.

Besides Mills, D. B. Cassidy, S. H. M. Deng and H. K. M. Tanaka of UCR; R. G. Greaves of First Point Scientific, Inc., Agoura Hills, Calif.; T. Maruo and N. Nishiyama of Osaka University, Japan; and J. B. Snyder of Principia College, Ill., were involved in the study. UCR and the National Science Foundation provided support.

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