What is antimatter and why does it matter?

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The place is England. The year is 1928. One of the founding theorists of quantum mechanics, Paul Dirac, is scratching his head because solutions to his equations have yielded unexpected results. For the solutions to make sense, he reasons, there must be a particle that has the mass of an electron but the opposite charge. At the time, such a thing was not known to exist.

Several years pass before American physicist Carl Anderson observes a "positive" electron, or positron that confirms Dirac's prediction.

Almost 80 years later, positrons and other antiparticles are still studied to try to answer fundamental questions about the universe and the matter it contains. Antimatter, as the name implies, can be described as the opposite of ordinary matter. Every particle in the universe has characteristics such as mass and charge. With antimatter, the mass remains constant, but the sign of the charge is reversed. All particles have an antimatter counterpart, even the chargeless neutron (Its constituent quarks do have a charge; the antineutron is composed of antiquarks).

Unlike matter, antimatter is not common. Unless you're in the upper atmosphere, or inside a particle accelerator, you're not going to stumble across it. "Antimatter was not always so rare," Stéphane Coutu, Penn State particle physicist says. There was a time when it was as prevalent as matter itself. "Right after the Big Bang," Coutu explains, "we believe there must have been exactly the same amounts of matter and antimatter…and yet owing to some small asymmetry in the laws of particle interactions, all of the antimatter and most of the matter in the early universe was annihilated. We are left today with the resulting matter-dominated universe." So the study of matter-antimatter interactions is a glimpse at the first few moments of a nascent universe.

To conduct his antimatter research, Coutu sends sophisticated detectors to the edge of the atmosphere on high altitude balloons. He looks for antimatter in the cosmic radiation that rains down upon the earth. This antimatter sprinkle can be a signature for all sorts of particle interactions that occur within our galaxy.

Some physicists, instead of observing antimatter produced via nature, study it by making their own in a particle accelerator. When ordinary particles are accelerated to very fast velocities and then collide with each other, Coutu explains, antiparticles can be borne out of the ensuing high-energy explosions. These antiparticles are short lived, however, and invariably meet their ordinary-matter match in a destructive process called annihilation.

Annihilation doesn't mean that the particles completely disappear, it just means that their energy is transferred to a different form, he adds.

Science fiction is rife with tales of high-energy particle annihilation, and indeed, antimatter weapons have appeared in current bestselling novels. This is unrealistic, Coutu says. "[It] would be very impractical owing to very great difficulties in producing and maintaining significant amounts of antimatter."

Technology that uses the properties of antimatter is actually feasible outside of science fiction, however. Positron emission tomography (PET) is a medical technique that can be used to detect cancer, measure blood flow and detect coronary artery disease. In PET scans, "a small amount of radioactive substance is injected into a person, which produces positrons upon decaying within the body," Coutu explains. "By detecting the high-energy photons (gamma rays) produced in the annihilation of positrons with electrons in the body, a map can be made of where the substance has spread within the body." While antimatter may never be used as a bomb, it certainly has a positive future in life-saving medical diagnostic tools, the anti-weapon.

Source: By Katie Greene, Research/Penn State

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