

Antimatter Annihilation

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Abstract— In modern physics, antimatter is defined as a material composed of the antiparticle or partners to the corresponding particles of ordinary matter. In theory, a particle and its anti-particle e.g., proton and antiproton) have the same mass as one another, but opposite charge and other differences in quantum numbers. For example, a proton has positive charge while an antiproton has negative charge.

Key words: Antimatter Annihilation, CERN, ALPHA

I. INTRODUCTION

A collision between any particle and its anti-particle partner is known to lead to their mutual annihilation, giving rise to various proportions of intense photons (gamma rays), neutrinos, and sometimes less-massive particle-antiparticle pairs. Annihilation usually results in a release of energy that becomes available for heat or work. The amount of the released energy is usually proportional to the total mass of the collided matter and antimatter, in accord with the mass-energy equivalence equation, $E = mc^2$.

Antimatter particles bind with one another to form antimatter, just as ordinary particles bind to form normal matter. For example, a positron (the antiparticle of the electron) and an antiproton (the antiparticle of the proton) can form an anti-hydrogen atom.

A. Introduction:

Physical principles indicate that complex antimatter atomic nuclei are possible, as well as anti-atoms corresponding to the known chemical elements. There is considerable speculation as to why the observable universe is composed almost entirely of ordinary matter, as opposed to an equal mixture of matter and antimatter. This asymmetry of matter and antimatter in the visible is one of the great unsolved problems in physics.^[2] The process by which this inequality between matter and antimatter particles developed is called baryogenesis. Antimatter in the form of anti-atoms is one of the most difficult materials to produce.

Individual antimatter particles, however, are commonly produced by particle accelerators and in some types of radioactive decay. The nuclei of anti helium have been artificially produced with difficulty. These are the most complex anti-nuclei so far observed.

B. Concept:

The idea of negative matter appears in past theories of matter that have now been abandoned. Using the once popular vortex theory of gravity, the possibility of matter with negative gravity was discussed by William Hicks in the 1880s. Between the 1880s and the 1890s, Karl Pearson proposed the existence of "squirts" and sinks of the flow of matter. The squirts represented normal matter and the sinks represented negative matter. Pearson's theory required a fourth dimension for the matter to flow from and into.

The term antimatter was first used by Arthur Schuster in two rather whimsical letters to *Nature* in 1898, in which he coined the term. He hypothesized antiatoms, as well

as whole antimatter solar systems, and discussed the possibility of matter and antimatter annihilating each other.

Schuster's ideas were not a serious theoretical proposal, merely speculation, and like the previous ideas, differed from the modern concept of antimatter in that it possessed negative gravity.

The modern theory of antimatter began in 1928, with a paper by Paul Dirac. Dirac realized that his relativistic version of the Schrödinger wave equation for electrons predicted the possibility of antielectrons. These were discovered by Carl D. Anderson in 1932 and named positrons (a portmanteau of "positive electron"). Although Dirac did not himself use the term antimatter, its use follows on naturally enough from antielectrons, antiprotons, etc. A complete periodic table of antimatter was envisaged by Charles Janet in 1929.

The Feynman-Stueckelberg interpretation states that antimatter and antiparticles are regular particles traveling backward in time.

II. NEED OF INVENTION

Antimatter annihilations convert the entire mass of the particles involved into energy, following Albert Einstein's famous equation $E = mc^2$. A great deal of energy can be produced from little mass a kilogram of matter annihilating with the same amount of antimatter will release around as much as the Tsar Bomb, the largest thermonuclear bomb ever built. Because of this, antimatter has been touted as a possible future weapon or source of fuel antimatter driven propulsion is a staple of science fiction. However, antimatter currently takes far too long to produce, and at too high an energy cost, for either weapons or fuel to be practicable. CERN claims it has taken several hundred million pounds to produce just a billionth of a gram, and that to make a gram of antimatter would take about a 100 billion years. The antimatter is the type of matter they produced high energy when come in contact with matter

III. TYPES OF SUBSTANCE

A. Matter:

Matter is any substance that has mass and takes up space by having volume. All everyday objects that we can touch are ultimately composed of atoms, which are made up of interacting subatomic particles, and in everyday as well as scientific usage, "matter" generally includes atoms and anything made up of these, and any particles (or combination of particles) that act as if they have both rest mass and volume.

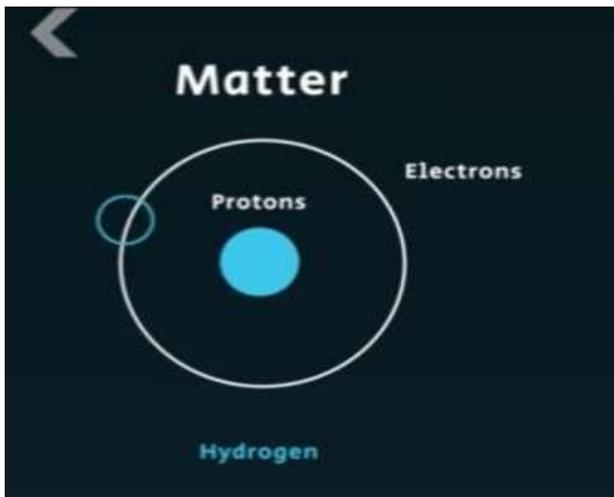


Fig. 1: Matter

B. Antimatter:

A particle and its anti-particle (e.g., proton and antiproton) have the same mass as one another, but opposite electric charge and other differences in quantum numbers. For example, a proton has positive charge while an antiproton has negative charge. A collision between any particle and its anti-particle partner is known to lead to their mutual annihilation, giving rise to various proportions of intense photons (gamma rays), neutrinos, and sometimes less-massive particle-antiparticle pairs.

IV. MANUFACTURING METHODS OF ANTIMATTER MATERIALS

- 1) ALPHA Experiment (Anti hydrogen laser physics apparatus)
- 2) AEGIS Experiment (Antimatter Exp gravity, Interferometry, Spectroscopy)
- 3) GBAR Experiment (Gravitational Behavior of Anti hydrogen at Rest)

A. ALPHA Experiment (Anti hydrogen laser physics apparatus):

The ALPHA experiment is designed to trap neutral anti hydrogen in a magnetic trap, and conduct experiments on them. The ultimate goal of this endeavor is to test CPT symmetry through comparison of the atomic spectra of hydrogen and anti-hydrogen (see hydrogen spectral series). The ALPHA collaboration consists of some former members of the ATHENA collaboration (the first group to produce cold anti hydrogen, in 2002), as well as a number of new members.

B. AEGIS Experiment (Antimatter Exp gravity, Interferometry, Spectroscopy):

AEGIS would attempt to determine if gravity affects antimatter in the same way it affects matter by testing its effect on an anti hydrogen beam. The first phase of the experiment creates anti hydrogen: antiprotons from the Antiproton Decelerator are coupled with positrons, making a pulse of horizontally-travelling anti hydrogen atoms. These atoms are sent through a series of diffraction gratings, ultimately hitting a surface and thus annihilating.

C. GBAR Experiment (Gravitational Behavior of Anti hydrogen at Rest):

The GBAR project, aims to measure the free fall acceleration of ultra-cold neutral anti hydrogen atoms in the terrestrial gravitational field. The experiment consists preparing anti hydrogen ions (one antiproton and two positrons) and sympathetically cooling them with Be^+ ions to less than $10 \mu\text{K}$. The ultra-cold ions will then be photo ionized just above threshold, and the free fall time over a known distance measured.

V. ANTIMATTER FUEL PRODUCTION PRINCIPLE (TRANSFORMING ENERGY INTO MASS):

When enough energy is squeezed into a very small space, such as during high-energy particle collisions at CERN, particle-antiparticle pairs are produced spontaneously.

The energy given to the accelerated particles has to be at least equivalent to the mass of the new particles in order for this to occur; the more energy that is put into particle collisions, the more massive the particles and antiparticles that can be produced.

When energy transforms into mass, both matter and antimatter are created in equal amounts.

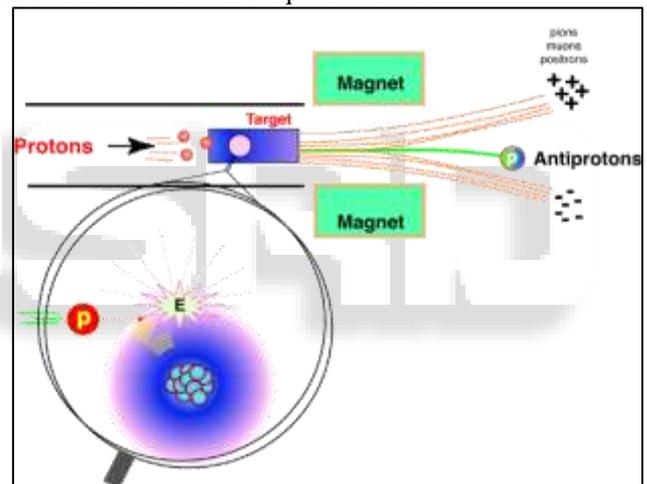


Fig. 2: Antiproton Decelerator (AD) working

VI. HOW STORED THE ANTIMATTER FUEL?

Atoms of antimatter have been trapped and stored for the first time by the ALPHA collaboration, an international team of scientists working at CERN, the European Organization for Nuclear Research near Geneva, Switzerland. Scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory and the University of California at Berkeley have made key contributions to the ongoing international effort.

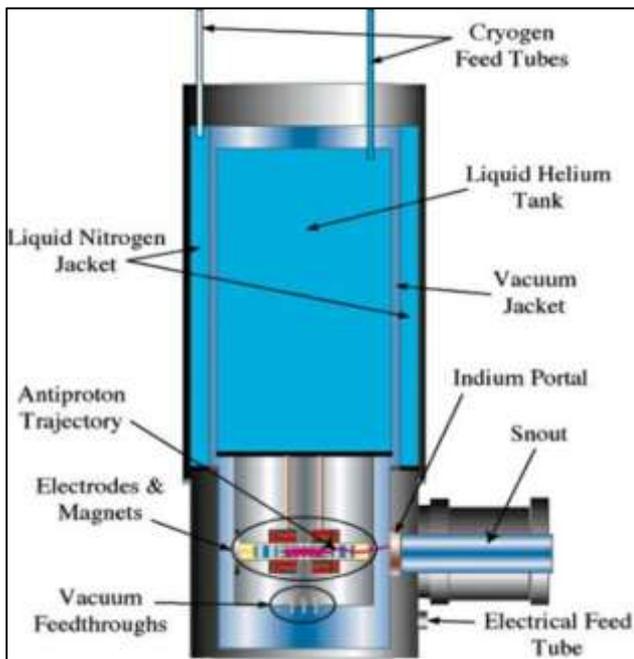


Fig. 3: stored cylinder

Trapping anti hydrogen proved to be much more difficult than creating anti hydrogen, says ALPHA team member Joel Fajans, a scientist in Berkeley Lab's Accelerator and Fusion Research Division (AFRD) and a professor of physics at UC Berkeley.

ALPHA routinely makes thousands of anti-hydrogen atoms in a single second, but most are too hot too energetic to be held in the trap. We have to be lucky to catch one.

The ALPHA collaboration succeeded by using a specially designed magnetic bottle called a Mini mum Magnetic Field Trap. The main component is an octu pole (eight-magnetic-pole) magnet whose fields keep anti-atoms away from the walls of the trap and thus prevent them from annihilating

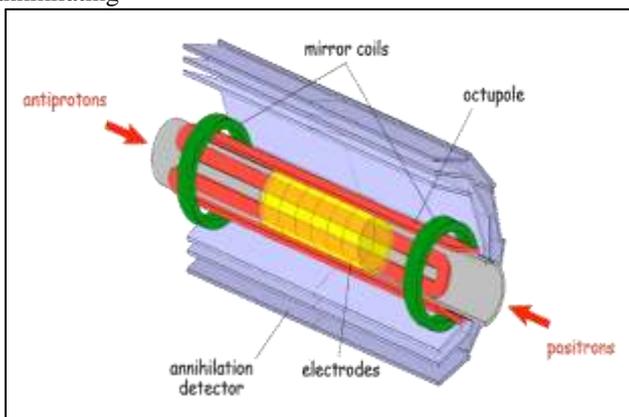


Fig. 4: Anti matter storage method

VII. WHAT ARE THE PROPERTIES OF ANTIMATTER?

There are compelling theoretical reasons to believe that, aside from the fact that antiparticles have different signs on all charges (such as electric charge and spin), matter and antimatter have exactly the same properties.

This means a particle and its corresponding antiparticle must have identical masses and decay lifetimes

(if unstable). It also implies that, for example, a star made up of antimatter (an "anti-star") will shine just like an ordinary star.

This idea was tested experimentally in 2016 by the ALPHA experiment, which measured the transition between the two lowest energy states of anti-hydrogen. The results, which are identical to that of hydrogen, confirmed the validity of quantum mechanics for antimatter.

A. Artificial Production:

1) Positrons:

Positrons were reported in November 2008 to have been generated by Lawrence Livermore National Laboratory in larger numbers than by any previous synthetic process. A laser drove electrons through a gold target's nuclei,

Which caused the incoming electrons to emit energy quanta that decayed into both matter and antimatter.

Positrons were detected at a higher rate and in greater density than ever previously detected in a laboratory.

Previous experiments made smaller quantities of positrons using lasers and paper-thin targets; however, new simulations showed that short, ultra-intense lasers and millimeter-thick gold are a far more effective source.

2) Decelerator (AD) Machine:

The different experiments which generally implode for the manufacturing antimatter material.

- 1) ALPHA Experiment
- 2) EGIS Experiment
- 3) GBAR Experiment

VIII. ALPHA EXPERIMENT

It is the one of the type of experiments with the help of which the Antimatter Material is manufactured by using the Antiproton Decelerator (AD) Machine.

A. Constructional Details:

The ALPHA apparatus uses a versatile Penning - Malmberg trap for trapping and manipulation of the charged particles used for anti-hydrogen production.

The left-hand part of the trap is enclosed by high voltage electrodes to catch the incoming antiprotons, whereas the right-hand section is used for transfer and manipulations of positrons transferred from the positron accumulator.

The center of the trap is the so-called mixing trap where the anti-hydrogen is formed. An anti-hydrogen atom can be trapped in a three dimensional magnetic minimum due to its magnetic dipole moment. If anti hydrogen can be created cold enough in the magnetic trap, or be cooled once inside it, it can be trapped.

Such a magnetic trap, where the transverse minimum is formed by using a multi pole magnet, and the axial minimum by a pair of pinch or mirror coils will,

When superimposed on the solenoid field of the Penning-Malmberg trap, have a transverse well depth U (in K).



Fig. 5: ALPHA Experiment conclusion:

Due to the highest energy release per unit mass of any known reaction we can say that antimatter will be a future fuel but need a reliable method of producing large amount of it.

The antimatter fuel is more expensive to produce and very complicated to store due to this disadvantages the antimatter fuel is not economical at any cost but the antimatter fuel is next generation of the fuel.

And the antimatter fuel is the future of the fuel.

Antimatter's fuel Advantages:

- 1) One of the beauties of antimatter is its High efficiency.
- 2) A fission reaction uses up about 1 percentage of the available energy inside matter, whereas the annihilation of antimatter and matter converts 100 percentage of the mass into energy.
- 3) No wonder tiny amounts of antimatter can have such powerful effects

Matter/antimatter reactions produce 10 million times the energy produced by conventional chemical reactions.

- 4) Less space required to stored antimatter fuel.
- 5) If mixing matter and the antimatter large amount of energy produced as compared to conventional fuel.

Antimatter's fuel Disadvantages:

- 1) However, humans have produced only a minuscule amount of antimatter
- 2) The problem lies in the efficiency and cost of antimatter production and storage.
- 3) Making 1 gram of antimatter would require approximately 25 million billion kilowatt-hours of energy and cost over a million billion dollars.
- 4) Antimatter fuel is very difficult to stored and expensive to produce.
- 5) Antimatter making machine (AM) Machine is very complicated and difficult to understand

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