Antimatter and Its Application-Collecting Antimatter and Storage It as Energy Source

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Abstract. As antimatter and its potential to use as an energy source is discovered by modern scientists, there are few reviews to introduce the history and applications of antimatter which is the aim of the paper. This paper provides a brief introduction to how antimatter was discovered and some possible applications of antimatter in the future. In this paper, the physics of antimatter and the creation, storage and using ways of antimatter will be described. After that, I will summarize the feasibility of utilizing the energy from the annihilation of antimatter-matter. And some possibilities of applications based on this energy, like antimatter ships and antimatter factories, will be discussed.

Keywords: Antimatter, history of antimatter, energy source, collection and storage of antimatter, applications based on antimatter energy.

1. Introduction

In 1905, which time is called the Einstein's-Miraculous-Year, Albert Einstein published his special relativity, which almost changed the way people explain the world. And he explained the relationship between space and time, energy and mass in the famous paper and got the famous $e = mc^2$. At the same time, experiments show that light sometimes behaves like waves, but sometimes it behaves as fast-moving photons. In the 1920s, physicists tried to apply this novel thinking to various atoms and their components to try to obtain new things. After thousands of attempts, Irving Schrodinger and Werner Heisenberg, two creative scientists, invented a new theory of quantum physics. However, a problem that cannot be ignored now is that the quantum theory is not relativistic, which means that the quantum description is only applicable to low-speed, slow-moving particles, but not to those particles with high (or can be called "relativity", because the particles in high-speed motion will show wave-particle duality). In 1928, things turned around. Paul Dirac successfully solved this problem: he wrote an equation combining quantum theory and special relativity to describe the behaviour of electrons. But at the same time, the Dirac equation raises another problem: the Dirac equation can have two solutions, one with positive energy electrons and the other with negative energy electrons, which makes people unable to easily accept and believe. Because in classical physics (and common sense), the energy of a particle can only be positive. In this case, Dirac explained that for every particle that exists, there is a corresponding antiparticle with opposite energy, which exactly matches the particle, but the charge is opposite. In order to promote his explanation, in Dirac's Nobel Speech, he speculated that there would be a new universe composed of antimatter [1]. In 1898, the British physicist Arthur

Schuster first introduced antimatter. Schuster wrote two letters to nature, in which he assumed that there were antiatoms in the solar system and the reaction of antiatoms when they came into contact with conventional atoms. Dirac developed a theory, now called the Dirac equation, which combines quantum mechanics (used to describe the subatomic world) with Einstein's special theory of relativity (used to explain the super large world). It explains the behaviour of electrons approaching the speed of light[2].

Like the proposition of quantum energy and the principle of constant speed of light, the proposition and establishment of the concept of the antiparticle is also a major breakthrough in physical science. Following the discovery of the positron in 1932, sigrady and Chamberlain, who worked at the University of California's large accelerator, discovered the antiproton in 1955, followed by the antineutron, antinucleon and antimeson. These include the anti-sigma hyperon discovered by Chinese physicist wangganchang when he worked in Dubna, the Soviet Union, in 1957. In order to generate an electron-positron couple, about 1MeV energy is required, while in order to generate a proton-antiproton couple and neutron antiproton couple, 2GEV energy is required so a larger accelerator is required[3]. There is a certain amount of energy required to produce particles and antiparticles. When particles and antiparticles meet and annihilate, this energy is released, while this can always be some uncontrolled explosion. So, antimatter must be kept in an absolute vacuum. Otherwise, it will produce an explosion, which is never heard of by human beings. And that may be why we can't throw antimatter into the large rate of energy production for now. These results strengthen people's belief that all particles that obey the Pauli exclusion principle have antiparticles and that antimatter exists in some part of the universe. It is quite possible that some planets are quite made of matter. They are mainly composed of positrons and negative protons. In fact, it is possible that the two kinds of planets account for half[3]. Actually, those planets could be considered as energy containers and stars waiting to explode as well..

Through the discovery of antimatter and the basic principle of physics, it is easy to know the necessity of considering the possibility of the application of antimatter. Recently, people are trying to put it in transportations. The energy produced by antiprotons could be utilized for propulsion to generate force, provide energy for propellants and heat solid cores. Therefore, there is a large number of concepts about antimatter propulsion[4]. To meet such large production demand, here we need to concept some production lines like antimatter factories to make and find enough antimatter in the universe. As an example which tries to build such a place where is to create antimatter, there is a strong belief based on Positron Dynamics that antimatter can do more. Some companies which have enough money to find out are trying to go further on this. It's gonna be a drastic shock compared to the current progress from isotope-based methods, and this may get enough to turn the work of creating positron into a renewable and sustainable business industry[5]. But what will be talked about first is the physics principles which make antimatter able to work as an effective energy source.

2. The energy contained in antimatter annihil ation

Antimatter consists of antiparticles with similar properties but opposite charges. Antimatter is a substance composed of antiparticles, which have similar properties but opposite charges. Each particle should have the "antipartner", which has the same property as itself, somehow with opposite charges. For example, while a proton is positively charged, the antiparticles called antiprotons have just the same mass. Basically, no essential difference exists between particle and antiparticle and the physical laws they obey are just identical. However, when a particle meets its antiparticle, they annihilate each other and release energy in the form of photons, gamma rays and other antimatters due to the law of conservation in physics. Because there is no way to release an elementary particle, the net charge on the system is 0. So, the only way is to let the elementary particles vanish anyway. Many properties of the system will become 0 as the values of electrons and positrons will set off each. The only possible solution, according to the mass-energy equation, is that the two particles should annihilate each other and release equal energy. The energy created by proton antiproton annihilation (nearly 1.8×10^{14} J per gram of reaction) is times the energy released by hydrogen-oxygen combustion and 100 times the

energy released by fission or fusion. This reaction has almost the highest energy density, which is why it could become a very fantastic energy source in the future[6]. When we could convert this source into any kind of source we want, the application of antimatter would be infinite. There will be a flood of improving energy production and long-distance travel like space transportation[6]. Storing antimatter is a highly efficient form of concentrated energy storage because antimatter converts all its mass into energy after annihilation with normal matter. However, unlike the antiproton, the antiproton will not be converted into gamma rays during annihilation, but two-thirds of its energy is emitted in the form of charged particles (π), and its kinetic energy can be converted into thrust through interaction with the magnetic field nozzle or working fluid. Many-particle physics laboratories around the world are already producing, capturing, cooling and storing antiprotons, albeit in small quantities. Antimatter will be valuable propulsion energy because it allows mass to be completely converted into energy[7]. When we put antimatter into production, we should know that when antimatter contacts the matter, it will annihilate, which means that the mass of particles and their antiparticles will be converted into pure energy.

3. The physics of antimatter

As we know, universe space is full of fields, like electromagnetic fields or the electron field. The field is any number which has a value wherever in the universe space. The value of the electron field in the dark union space would be zero. When there are electrons, the electron field has a positive value. Where there are antielectrons, the electron field has a negative value. So, as someone adds both positive and negative values, the sum should be zero. As the electrons and positrons meet, they both cease to exist or annihilate. The loss of mass could excite the electromagnetic field and produce two photons as an energy form.

For us, we regard the earth and other stars as composed of negative electrons and positive protons. In some cases, however, the opposite may be true. Stars are mainly composed of positrons and negative protons. In fact, there may be half of every kind of star. Unfortunately, these two kinds of stars will show the same spectrum, which cannot be distinguished by current astronomical methods[8].

To make the physics of antimatter clear, we could find some formulas to describe those specialities of antimatter, and these empirical formulas could have significant contributions to the collection of antimatter [9]. But it is not simple work to find those planets that are definitely big stars containing a large source of antimatter. However, there are still some other ways for us to find antimatter in the universe.

4. Some ways to collect antimatter

To collect those high potential particles, antiprotons and positrons are constantly produced in space which is not enough, and they are regularly produced by humans on earth. Collecting these particles in space and forming stable antimatter atoms and molecules will create an important energy source for power and propulsion. Although the energy consumed by specially manufacturing these particles on earth is much more than the energy released after annihilation, the antimatter produced represents a high-density energy storage mechanism[10]. That is the main application where the paper is gonna be.

Robert forward once talked about antimatter factories in space, which will mainly get power from the sun. As Robert forward, he came up with a great idea: to build a 100km collector array on one side to generate ten terawatts of power input, which is enough to drive several antimatter plants with full power and produce one gram of antimatter per day. Bickford's idea was to use a plasma magnet to make a magnetic shovel that could affect the trajectory of charged particles over long distances. In the equatorial orbit around the earth, such a spoon can capture the antiparticles occurring in the planetary radiation belt because they obey the Lorentz force and bounce back and forth between the mirror points in the northern and southern hemispheres. The antiproton belt used by our spacecraft is similar to the proton in the Van Allen radiation belt. Before we observe the solar system, it provides a close-up source of antimatter, where we find more storage, especially around Saturn. In his report, Bickford talked about the high-temperature superconductors and their use to form RF coils. A large amount of

energy is required to operate the system, which can be supported by nuclear power or solar energy. It is simple to understand: the magnetic field driven by the RF coil concentrates the incoming antiprotons and captures them [11].

5. Storage of antimatter

Research and development projects in the area of antimatter storage, at the quantities of antimatter needed for space-related power and propulsion applications, are pursuing two different directions (Nieto et al., 2003). On one side, there is considerable effort devoted to the formation and storage of stable positronium (Ackerman et al., 1997). On the other side, even more the effort is currently being devoted to understanding how to form and store antihydrogen. Results from work on stable positronium are not currently available to the general scientific community due to security concerns[10].

In the case of antiproton storage, perhaps the optimum form would be charged specks of anti-lithium formed via a chain of antimatter fusion reactions. While strategies exist for producing low-energy antineutrons, these concepts are yet too conceptual to be presented here. Therefore, the interim solution is to form antihydrogen atoms (Jackson, 1997), which are cryogenically stored in the form of charged antihydrogen flakes. These microscopic flakes would each be levitated in a three-dimensional electrostatic trap employing active feedback to position the flakes in the centre of six micron-scale electrodes. Extraction of these charged flakes would be accomplished by a bucket-brigade type transport architecture, similar to that of CCD camera pixels, wherein the thousands of traps would kick the flakes to their nearest neighbours[10]. Since antimatter annihilates on contact with matter, it can't be stored like any other substance. Antimatter shouldn't contact any matter while it is stored. This would be done by using the property of spin magnetic moment, which antimatter has. Using magnetic and electric fields, a force is applied to the antimatter, which directs it away from any matter. That means the possible most effective way for storing antimatter is to ionize antimatter into gas. And then store it in a small magnetic container, which won't allow the antimatter to react on the sides of the storage box[12].

6. Possible future applications

There is no doubt that antimatter is a kind of powerful material which may produce a thousand times the energy of nuclear fission reaction. Using hydrogen as the working fluid heated by antimatter and 10 mg of antimatter can give you 120 tons of traditional rocket fuel stimulation. If we can reduce the cost to $ 10 million per milligram, antimatter propulsion will be cheaper than nuclear fission, depending on the efficiency of the design[13].

6.1. Antimatter ship

Here I would simply talk about some theories and technologies that may be used on space ship one day. For now, only large facilities with enough power can produce protons. Antiprotons are produced by sending protons close to the speed of light into metals (usually tungsten). It is very difficult to collect and store antiprotons safely from facilities as they would react with matter. Scientists have to use electromagnetic fields to prevent the explosion[14]. The point particles produced by antimatter annihilation can be used to generate direct propulsion, while antiprotons provide energy for propellants or heat solid cores. There are many different concepts about antimatter propulsion. The simplest concept is to use antiprotons to heat the metal core sold, usually tungsten. A small hole is made in the cylinder, in which there is a core into which hydrogen can enter. When hydrogen enters, the tungsten core is cooled, and hydrogen is heated. The hydrogen propellant is then expanded through the nozzle to generate thrust[4]. The performance of thrust rockets generated by solid antiproton nuclei is roughly equivalent to that of nuclear rockets[4]. Another concept of propulsion is to use a plasma core instead of a beamed core. Antiprotons are injected into the plasma core to annihilate and heat the plasma. Heat is rapidly transferred to the propellant and released from the aircraft at a very high rate[4]. The concept of beam nucleus deviates from the concept of the secondary heating fluid. In the

core content of the beam, the charged particles annihilated by antiprotons directly release carriers [Schmidt] at a very high speed close to the speed of light along the axial magnetic field.

To successfully build up an antimatter spaceship, building up a stable production line of antimatter would be the first step.

6.2. Production line of antimatter

From the above descriptions, it is easy to see the potential of antimatter as an energy source in the future. CERN has a very interesting machine called an antiproton retarder (AD). This machine began its function in 2000 and has been used in Athena, antihydrogen production and precision experiments. These experiments began in 2001 and are still used today. At the same time, it is still used in the experiments started in 2014, called the base, baryon Antibaryon symmetry experiment. The tool actually needs the help of a so-called proton synchrotron to create protons. CERN scientists actually use a beam of protons, a high concentration of very small particles called protons, which they aim at and emit from metal plates. Once these protons touch the metal plate at high speed, the result is a seemingly destructive collision at the subatomic level. The result of this collision is actually the production of many different subatomic particles, one of which is antiproton or positron, and it is abundant[15]. However, there is a small problem at this point. Antiprotons are of no use to scientists. They don't have the right energy and can't be controlled at present. This is the source of the name antiproton retarder. Antiprotons actually have so much energy that they are unstable and frantically moving that they cannot be used. Antiproton retarders actually slow them down and control them. Ad will make antiprotons available for experiments so that scientists can learn more about them. It is actually very interesting that the ad does not actually produce these antiprotons, but it allows them to be studied. Using the same idea as the magnetic field and electric field proposed in the previous article, the antiprotons created in the last step fall off the metal plate at different angles because they are the products of collision. They are concentrated at a single-entry point, and only some of these antiprotons can manage to enter. Once in the antiproton reducer, which is a beautified storage unit, magnets are used to guide antiprotons, while electric fields are used to actually slow them down. Remember I said that at low speeds, antimatter actually starts to behave like a very weak and very small magnet. This process of reducing the antiproton speed is called cooling. They actually go through several rings, which are antiproton reducers, until they reach a speed equivalent to one-tenth of the speed of light. From this point on, they are bounced out for the experiments that scientists want to carry out[15].

With such efforts of previous scientists, it comes that people can hardly make a machine which is able to produce a stable and meanwhile large number of antimatters. So, what people should consider first before making an antimatter production line is to find a way to make enough stable antimatter and a safe way to store and transport it.

6.3. Antimatter factories

It is a concept that is hardly mentioned. If we can control the antimatter completely, the energy could open a new generation of technologies, for example, molecular scanners, rocket engines and even the "annihilation lasers", which is a tightly focused energy beams driven by annihilation positrons. However, although recently there have been some breakthroughs in making the particles, it is still difficult to capture and contain them[5]. Many positron scientists believe that within five years from now, we will have the technology for transporting positrons. The positron has been applicated in the technologies like imaging, especially medical field, such as positron emission tomography, as they have X-ray ability to identify high metabolic activity points in the body. And the particle with positive electricity has the trend to be embedded in atomic gaps of metals. Therefore, weed envisioned a positron scanner that could find sub microscopic defects in semiconductors or aircraft engines. Given the right storage breakthrough, weed estimated that the scanner could be ready for use in just three years[5]. This is most likely to say, there are some ways to control antimatter, but we have not completely understood them.

Till that time to have the ability to build the factories that locates the antimatter production line, scientists still get many problems to solve.

7. Conclusion

Above all those descriptions, we can find out that the antimatter should be in the form of antiprotons. People could get the energy emitted as particles in charge(pions) from antimatter annihilation. Its kinetic energy can be converted into thrust through interaction with a magnetic field nozzle or working fluid. From this point of view, to put it in some machines to create space ships is no more a dream. However, when people need to get enough antimatter power, it is not that easy. To collect those high potential particles, antiprotons and positrons are constantly produced in space which is not enough, and they are regularly produced by humans on earth. This also means that people should consider building a whole, effective antimatter production line before putting it into large industrial production. While there are few ways to save antimatter stalely and safely, it's still not common energy this time. At present, because the cost is too expensive, there is no energy-saving method using antimatter as energy. Although the pure high energy of the reaction between matter and antimatter may be a major core for mankind to solve the energy problem in the future, antimatter is not feasible energy at present unless we find ready-made antimatter sources on the earth or design a method to significantly increase the production of antimatter. But sooner or later, we will find an effective way to store and release antimatter and make full use of antimatter energy.

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