The Proton-Proton Chain: An Energy Solution

Introduction

Over the past few years there has been a growing desire in the world population to discover new methods of obtaining energy without environmentally harmful byproducts. Our solution may be as easy as looking up at the stars, or to be more specific our sun. Our sun, and others like it, produces its massive amount of energy through a process called the proton-proton chain ("Proton-Proton Cycle"). With technology advancing like it is now; could we harness true solar power for our growing energy needs?

Part I: What is the Proton-Proton Chain?

Through the advancements of chemistry and astronomy, scientists have learned what powers our sun and other stars like it. The element that powers our sun is the simplest of all elements, hydrogen, which is why fusion takes place at such "low" temperatures ("Stars: Hydrogen Fusion"). This pathway of nuclear fusion is easiest to replicate because hydrogen only has a single proton in its nucleus. This is important because protons push away from other protons that are not part of the same nucleus (Doyle). The more protons in an atom's nucleus the more energy required to push the two together. When the two nuclei have enough energy to ignore their magnetic fields, nuclear fusion will occur, giving off more energy than what was required to fuse the atoms together (Doyle). Our sun uses the proton-proton chain which is efficient in the way it produces energy; only 2% of the energy given off by the reaction is needed to start the fusion process. ("Stars: Hydrogen Fusion"). The temperature needed for the first stage of the proton-proton chain can be achieved at temperatures less then 1 million Kelvin, but the last step can only be achieved at temperatures well over 10 million degrees Kelvin (Smith).

The first step to the chain is a single hydrogen atom fusing with another hydrogen atom; this will release a high energy positron, transforming a proton to neutron, and a neutrino (Doyle).

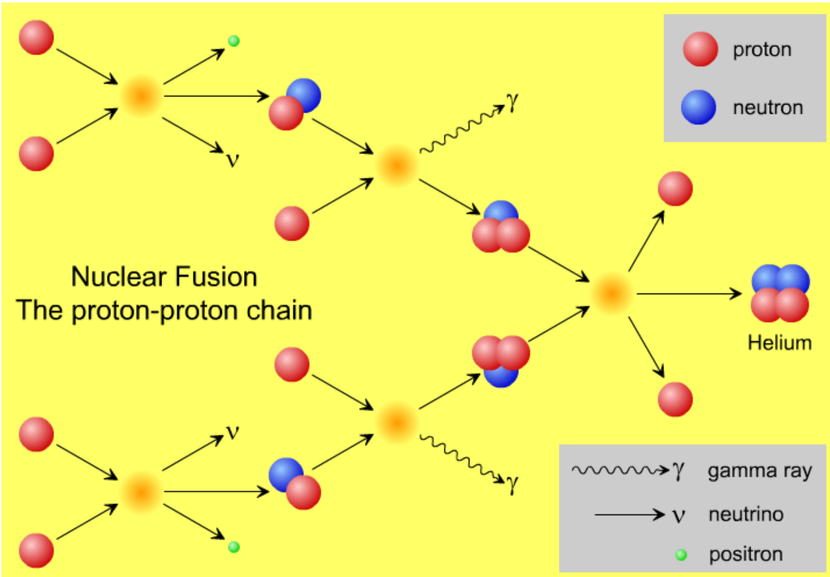

Fig.1. This figure shows the steps of the proton-proton chain and what each step gives off as its products.

A neutrino is a peculiar particle that has nearly no mass, like an electron, but has a neutral charge (Casper). The created positron smashes into one of the orbiting electrons destroying both particles but creating a high energy photon called a gamma ray (Doyle). This first step has created energy in the form of a gamma ray and the hydrogen isotope deuterium, which is made of a proton and a neutron (Doyle). The next step in the chain fuses the deuterium that was just made with another hydrogen atom; this creates another high energy gamma ray and the helium isotope helium-3 (Doyle). The final step is when two separate helium-3 isotopes fuse together to form a helium atom, helium-4, and expelling two protons (Doyle). This final step can only be done at much higher temperatures than the other two steps, because of the extra proton in the nucleus of each helium isotope (Doyle). The mass of a helium atom is much less than the mass of the 4 hydrogen atoms that created it, the missing mass was converted to energy, as explained by Einstein's equation Energy = mass times the speed of light squared (Doyle).

Part II: Current Fusion Technology

Of course we wouldn't know so much about fusion if we, mankind, hadn't already achieved success with it. Countries have been able to replicate another form of hydrogen fusion, known as tritium-deuterium fusion, via the testing of hydrogen bombs; though these reactions only last for a microsecond (Kruger 134). Scientists have been working for about half a century to harness the power of fusion, which they have hopes in the deuterium-tritium reaction.

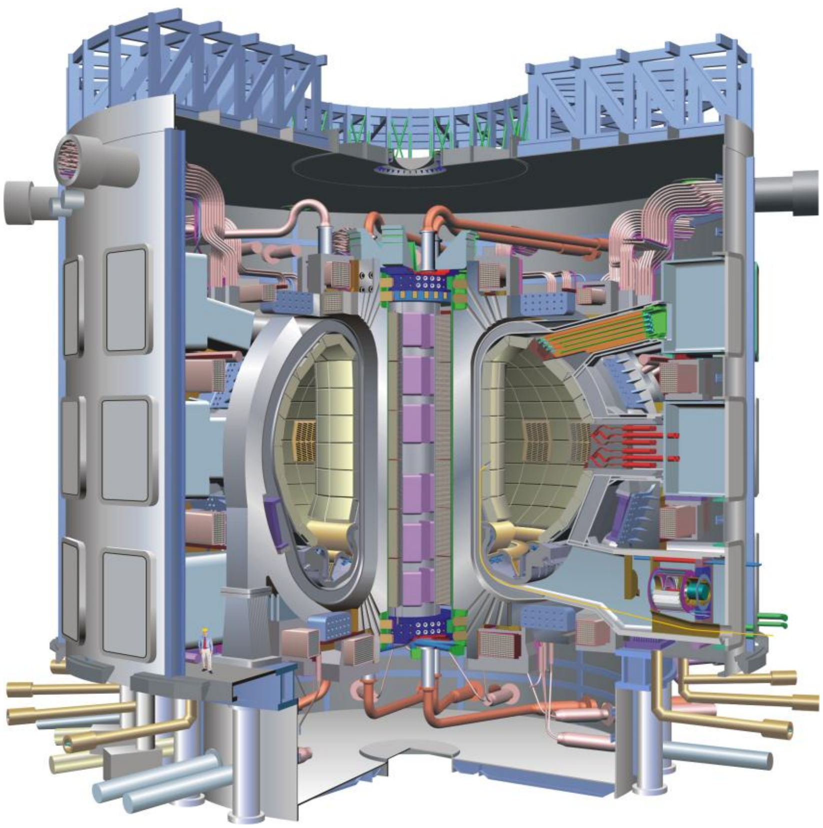

Fig.2. This is the inside of a tokamak fusion reactor, with its characteristic "donut" vacuum chamber in the center.

Scientists hope to use tokamaks, a donut shaped fusion reactor to achieve their goal of fusion for energy (iter). They want to use deuterium fuel for the reaction and have the reactor "blanketed" with lithium panels, allowing the reactor to "breed" tritium needed for the fusion process (iter). The reactors, called tokamaks, are donut shaped fusion reactors with super conducting alloy panels protecting the inside from extreme heat (iter). The tokamaks also use electromagnets to create powerful magnetic fields inside the reactor to prevent the superheated plasma, which is at 15 million degrees Celsius, from touching the walls of the reactor (iter).

Part III: Is this Our Energy Solution?

With technology advancing at the rate it is, the proton-proton chain could very well be our energy solution for the future; even though scientists have not been able to find a way to replicate the proton-proton chain just yet. Currently our best research tool to learn how to achieve the proton-proton reaction is through deuterium-tritium fusion. To be more specific, future fusion technology will probably develop out of the ITER program in France (iter). ITER is an international project consisting of the European Union, China, Japan, South Korea, The Russian Federation, and the United States to build the largest tokamak ever for fusion research (iter). Scientists have not been able to replicate the chain because the number of reactions that must take place is too complex for current science. The chain would be harder to replicate compared to the deuterium-tritium reaction. ITER will be super heating its fuel to a plasma state of 15 million degrees Celsius, the same temperature as the Sun's core (iter). This extreme temperature will be reached via two heating methods that will be done outside the tokamak's core (iter). Scientists are heating the plasma to this extreme temperature so they may try and make a "burning plasma" which will let the plasma sustain itself without the need of adding more energy after the initial ignition (iter). If we are ever going to be

Fig.3. This is a picture of what the ITER facility will look like when it is completed, located in Cadarache in southern France.

able to replicate the proton-proton chain, the ITER program is our best research tool for finding out how.

Conclusion

The world needs a solution to our energy crisis. What is needed is a powerful source of energy that is clean and cost effective. One possible solution would be to replicate the proton-proton chain, the same way the sun produces its energy. The proton-proton chain is fueled by hydrogen atoms that are fused together to build larger atomic structures, which give off some of their mass as energy. Through the chain's three steps, a large amount of energy is produced with only two hydrogen atoms and a helium atom as its byproducts. Currently, scientists have only been able to use hydrogen fusion to fuse deuterium and tritium, the two isotopes of hydrogen. Our best path to finding a way to replicate the chain is in the ITER program; a program to construct the largest tokamak reactor in the world to conduct fusion research. Hydrogen fusion, including the proton-proton chain, is the solution to the world's energy needs.

Sources

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Images

Fig 1-"the proton-proton chain." The Solar Furnace. Web. 26 Nov 2010. <http://www.windows2universe.org/physical_science/physics/atom_particle/proton_proton_chain.gif>.

Fig 2-"The tokamak reactor." The ITER project. Web. 26 Nov 2010. <http://www-cadarache.cea.fr/gb/img/Tokmak_ITER_cut.jpg>.

Fig 3-"Cadarache." The ITER project and Belgium. Web. 26 Nov 2010. <http://www.iterbelgium.be/files/upload/cadarache_large.jpg>.