IS DEUTERIUM FUSION CATALYZED BY ANTINEUTRINOS?

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Abstract

The hypothesis of Fischbach and Jenkins that neutrinos emitted from the sun accelerate radioactive decay is noted. It is thought that neutrinos accelerate beta decay by reacting with neutron-rich nuclides to form a beta particle and a daughter product, with no antineutrino emitted. Conversely, it is proposed that antineutrinos can react with proton-rich nuclides to cause positron decay, with no neutrino emitted. It is also proposed that the nuclear fusion of the hydrogen bomb is triggered not only by the energy of the igniting fission bomb, but by the antineutrinos created by the rapid beta decay of the daughter products in the fission process. The contemplated mechanism for this chain reaction fusion process is the following: (1) The antineutrinos from the fission daughter products cause positron decay of deuterium by the process outlined above. (2) In a later fusion step, these positrons subsequently react with neutrons in deuterium to create antineutrinos. Electrons are unavailable to annihilate positrons in the plasma of the hydrogen bomb. (3) These antineutrinos thereafter react with more deuterium to form positrons, thereby propagating the chain.

Introduction – Reactivity of Neutrinos and Antineutrinos

Neutrinos and antineutrinos are one of the fundamental particles that make up the universe.[1] As neutrinos interact with only the weak force, they have been described as "feebly interacting,"[2] and "able to pass through great distance of matter without being affected by it."[1] Neutrinos are so feebly interacting that $6.4 \text{ X } 10^{10}$ neutrinos, almost all emitted from the sun, are predicted to pass through every square centimeter of the Earth per second.[3] While the actual neutrino flux has been measured to be lower than the predicted neutrino flux due to neutrino oscillation, the fact remains that a large quantity of solar neutrinos pass through the Earth and the vast majority of them fail to experience any interaction.

Neutrinos are created by standard positron decay, wherein a proton is converted into a neutron, and a positron and a neutrino are emitted. As fusion reactions in which protons are converted into deuterons to form deuterium, tritium, and helium isotopes occur in the sun in vast quantities, a similarly vast amount of neutrinos are emitted from the sun (see Frey, page 7 Figure 3). In contrast, antineutrinos are created as part of standard beta decay, wherein a neutron is converted into a proton, emitting a beta particle and an antineutrino. The greatest antineutrino flux known on Earth occurs in nuclear fission reactors, specifically due to the rapid beta decay of the daughter products of nuclear fission. For the purpose of this paper, the term "neutrino" refers only to neutrinos emitted with positron decay, and does not refer to both neutrinos and antineutrinos.

Recent research by Jenkins et al.[4] indicates that neutrinos may not be as feebly interacting as previously thought. Jenkins et al. present evidence showing that the decay rate of the nuclides ^{32}Si, a beta decaying nuclide, and ^{226}Ra, an alpha decaying nuclide vary with the annual variation of Earth sun distance. (Due to annual modifications in the Earth's orbit, the Earth is closest to the sun in January, and furthest from the sun in July.) The data presented by Jenkins et al. seems to indicate that the decay rate constant of the above-mentioned nuclides is greater when the Earth is closest to the sun. Jenkins et al. propose that this effect is caused by interaction of the radioactive nuclei with the neutrino flux emitted from the sun (wherein said neutrino flux is greater when the Earth is closest to the sun). They support this hypothesis by presenting further evidence suggesting that the decay rate of ^{54}Mn is increased during solar flares, when the solar neutrino flux is greater.[5]

The author is unaware of a mechanism regarding the effect of neutrinos on alpha decay. However, a mechanism for the effect of neutrinos on beta decay has been proposed.[6] According to this mechanism, which is shown in Figure 1, in normal beta decay, a neutron decays to a proton, sending out an electron (beta particle) and an antineutrino, resulting in a first order rate. However, in sun-induced beta decay, a neutrino interacts with an atomic nucleus to emit an electron (beta particle) with no antineutrino emitted. This sun-induced decay results in an increase in rate over and above the standard first order decay.

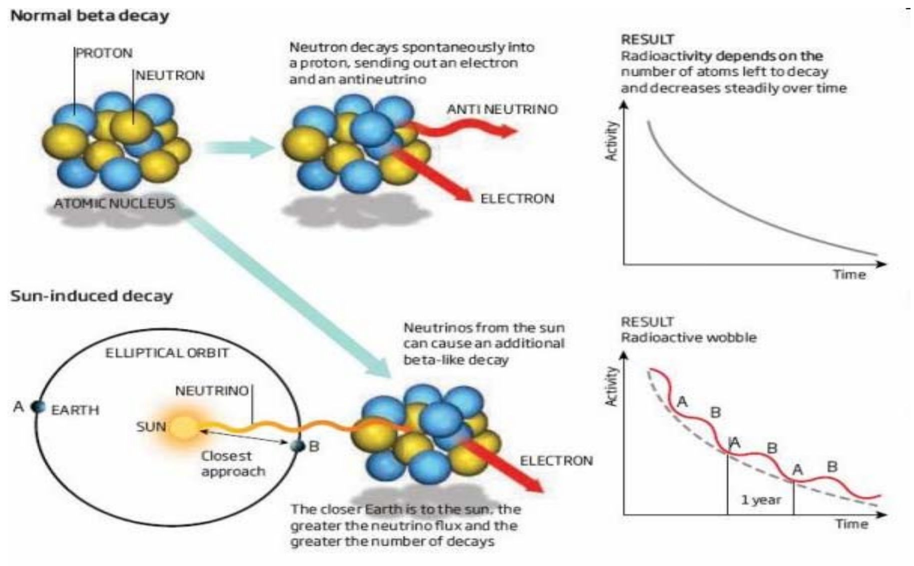

Figure 1: Regular Beta Decay vs. Sun Induced Beta Decay. This figure was obtained from Reference[6]

Introduction – Nuclear Fusion

Humanity is interested in nuclear fusion for its immense potential to produce large quantities of energy.[7] Nuclear fusion of Deuterium to form Helium produces energy because the mass of the product nuclides is slightly less than the sum of the masses of the reactant nuclides. This “missing mass” is converted to energy according to Einstein’s famous equation $E=mc^2$. Due to the large amount of energy produced per atom fused, and the abundance of Deuterium in our oceans, the quantity of energy that could theoretically be obtained through fusion is orders of magnitude greater than that produced by the energy sources that are in use today.

As nuclei are quite small, yet highly positively charged, there is a significant electromagnetic repulsion (i.e. a Coulombic barrier) in regards to pushing nuclei close enough together such that they may fuse. Hence, it is difficult to prod nuclei into undergoing fusion.

Humanity's efforts to extract energy from nuclear fusion have been disappointing. Nuclear fusion research has been in full force since after World War II, yet no approach to fusion, including tokamaks, fusors[8], lasers, and cold fusion, has successfully released more energy from fusion than that required to ignite the reaction, except for one notable exception. That exception is the hydrogen bomb. In the hydrogen bomb, an atomic fission bomb utilizing isotopes such as ^{235}U is ignited in the presence of deuterium, and said fission reaction initiates a nuclear fusion reaction, wherein deuterium fuses to helium. While useful for military purposes, the hydrogen bomb is too uncontrolled to be useful as a power source.

The success of the hydrogen bomb is usually explained by the fact that the nuclear fission imparts a great deal of energy to the deuterium nuclei. This energy allows the nuclei to overcome the Coulombic barrier, getting so close to each other that they are able to interact via strong nuclear force. As the strong nuclear force is attractive in nature, nuclei interacting by the strong force are able to fuse.

Proposed Theory – Nuclear Reactions

Given the theory proposed by references 4-6 above that solar neutrinos interact with neutron-rich nuclei like ^{32}Si to promote beta decay, the author proposes that the converse is likely to be true: that antineutrinos react with proton-rich nuclides to cause positron decay. While such a conversion has already been used to detect antineutrinos by Reines and Cowan[9] the author is merely proposing that such a conversion has a greater cross-section than previously predicted.

The author proposes the existence of positron-capture decay as the converse of electron capture decay. In electron capture decay, an electron interacts weakly with a nuclide, wherein it is captured by a proton to form a neutron, thereafter releasing a neutrino. In positron capture decay, a positron interacts weakly with a nuclide, wherein it is capture by a neutron to form a proton, releasing an antineutrino. The author is unaware of any reported experimental evidence of such a nuclear conversion, yet is also unaware of any evidence that prohibits such an interaction.

It is recognized that a conversion of a positron and neutron to form a proton and antineutrino as described above would be difficult to replicate experimentally. This is because of the ubiquity of electrons available to annihiliate with a positron. Also, if the positron were to react with a neutron-rich nucleus as opposed to a free neutron, the interaction would be further inhibited by electrostatic repulsion between the positron and the nucleus. However, the author still submits that such an interaction is possible.

The necessary nuclear reactions are described in Table 1 on the next page.

Neutron → Proton Conversions:	**Proton → Neutron Conversions:**
Beta Decay Antineutrino Decay	Positron Decay Neutrino Decay
Beta Decay Neutrino Capture	Beto Decay Antineutrino Capture
Positron Capture Antineutrino Decay	Beta Capture Neutrino Decay

Table 1: Relevant Nuclear Interactions: It is noted that the term “decay” refers to a product (e.g. in beta decay, a beta particle is produced as a product), whereas the term “capture” refers to a reactant (e.g. in electron capture, an electron is captured as a reactant).

Does Activation Energy Alone Promote Fusion?

As noted above, the “usual” explanation for the success of the hydrogen bomb is that nuclear fission bomb imparts a great deal of energy to the deuterium nuclei, allowing the nuclei to overcome the electrostatic repulsion keeping them apart and thereby fuse. The author disagrees.

In support of this position, the author notes that, according to the de Broglie equation and the Heisenberg Uncertainty Principle, the “size” of an atomic nucleus would be expected to decrease with increasing energy. The De Broglie relation shows that the wavelength of a particle, such as a proton or electron, decreases with increasing momentum. If such a particle is envisioned as a circular or spherical wave, not unlike a full stadium full of people doing “the wave,” then its circumference (i.e. wavelength), and subsequently its radius, would be expected to decrease with increasing momentum. The Heisenberg Uncertainty Principle also shows that uncertainty in position and uncertainty in velocity are inversely proportional. Hence, greater velocity of a particle leads to greater uncertainty in velocity, and thereby less uncertainty in position. The result of this is the compression of a particle into a smaller size at greater momentum.

As increased particle energy is correlated with increased velocity and momentum, a high energy proton would be expected to have a smaller wavefunction than a low energy proton. Hence, while the act of providing large quantities of energy to a system of protons or atomic nuclei would help those nuclei overcome electrostatic repulsion, it would also cause the nuclei to shrink in size. As electric charge does not change with size, the result of this is that nuclei would be required to overcome an even greater Coulombic barrier before being affected by the strong force.

This hypothesis is supported by the fact that a slow neutron is more likely than a fast neutron to result in activation of a nucleus, as was discovered by Enrico Fermi in the 1934.[10] The increased cross-section of slow neutrons may be caused by an increase in strong force attraction experienced by slow neutrons as opposed to fast neutrons, and may be partially applicable to their increased size.

Antineutrino-Catalyzed Fusion

Alternatively, the author proposes that the nuclear fusion reactions of successful hydrogen bombs have occurred by a different mechanism. Specifically, the proposed mechanism is a chain reaction comprising initiation, propagation, and termination steps, wherein a positron and an antineutrino are both produced and consumed by the propagation steps.

Initiation Steps:

^{235}U + neutron → fission products

Fission products → other products + β^- + antineutrino

^{2}H + antineutrino → neutron + neutron + β^+

Propagation Steps:

Neutron + β^+ + ^{2}H → ^{3}He + antineutrino

^{2}H + antineutrino → Neutron + Neutron + β^+

Potential Termination Steps:

β^+ + β^- → gamma rays

β^+ + neutron → proton

Antineutrino fails to interact

The summation of the propagation steps is the following:

~~Neutron~~ + ~~β^+~~ + ^{2}H → ^{3}He + ~~antineutrino~~

^{2}H + ~~antineutrino~~ → ~~Neutron~~ + Neutron + ~~β^+~~

This yields: **^{2}H + ^{2}H → ^{3}He + Neutron**

The mechanism of a chemical chain reaction is shown for comparison:

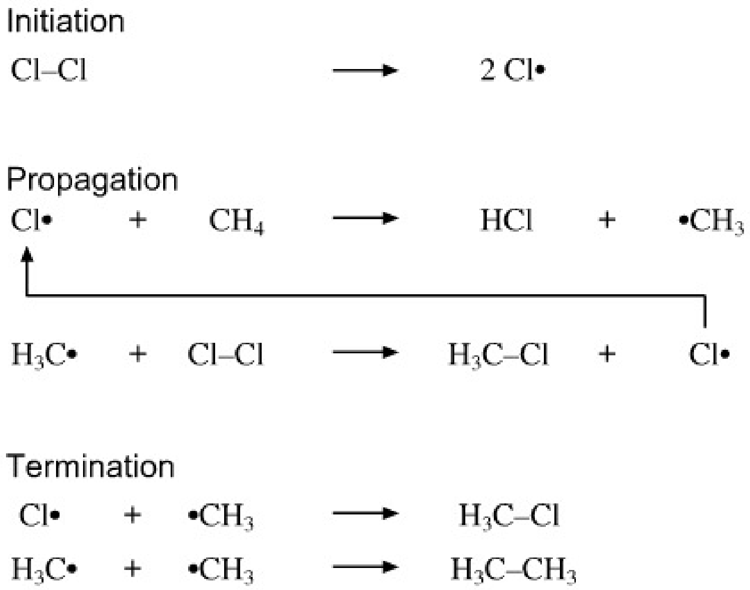

Figure 2: Free Radical Halogenation. Note the two reactive intermediates Cl* and CH3* produced and consumed by the propagation steps. This is similar to the production and consumption of the neutrino and antineutrino. This diagram was obtained from Reference[11].

Discussion: Limitations of Theory

The proposed theory obviously has many limitations. The most apparent limitations is that it is difficult to expect that neutrinos and antineutrinos, which interact so feebly that the vast majority pass through the Earth untouched, can interact with Deuterium atoms in a sufficient quantity as to sustain a nuclear fusion reaction. Another issue is that Deuterium is a stable isotope; therefore, the induction of positron decay by antineutrinos would not be expected. To address both of these issues simultaneously (in a limited manner), the author notes that electric fields have been known to affect beta decay[12], so therefore they may affect positron decay as well. Moreover, the close packing of the positively charged nuclei in an energetic plasma may cause their positron decay to be thermodynamically favorable, as the electrostatic repulsion may destabilize the reacting Deuterium nuclei and make them more vulnerable to positron emission.

Another limitation is that the likelihood of positron-electron annihilation would prevent the positron from being able to interact with a neutron to propagate the chain. Additionally, the author is unsure if evidence exists regarding whether positrons and neutrons interact at all. To address this limitation in a limited fashion, the author hypothesizes that positive and negative charges may have been sufficiently separated in the plasma state of the hydrogen bomb such that positrons may interact with neutrons before being exposed to the electrons. However, the author is unaware of evidence to back up this assertion.

Theoretical and Experimental Testing of Antineutrino Catalyzed Fusion

It goes without saying that any novel hypothesis must be tested. Mechanisms by which the hypothesis of antineutrino catalyzed fusion can be tested scientifically are proposed below.

On the theoretical front, calculations performed in the 1940s and 1950s regarding the power output and input of the hydrogen bomb should be re-examined. These calculations should be analyzed specifically with regard to whether the shrinking of the nuclear wavefunction in the presence of increased energy, as predicted by the de Broglie relation, was properly taken into account. If this factor was overlooked, that may lend support for an alternate theory of fusion-fission hybrids in the hydrogen bomb, such as that proposed here.

On the experimental front, it is noted that accurate detection of antineutrinos and positrons is difficult. Detection of antineutrinos is difficult because they “interact feebly” under normal conditions. Detection of positrons is difficult as well. Although positrons annihilate with electrons to produce two 512 keV photons, such photons may be produced by other means in a high energy plasma. Specifically, photons of 1 MeV or greater may produce a positron-electron pair, which will subsequently annihilate, producing two 512 keV photons.[13]

However, other experimental tests may be conducted to examine the veracity of this mechanism. One such test would involve the mixing, in an existing fusion reactor, of a subcritical amount of fissionable material along with fusion reactants. A particularly useful fissionable isotope would decay to form fission daughter products that undergo quick beta-decay to produce antineutrinos. Also useful would be the property of being activated by fast neutrons, because the highly energetic fusion product neutrons will further promote the fission reaction. One isotope that seems to fit these criteria is ^{238}U.

Such a system should be compared with a control, wherein the fusion fuel is presented in the fusion reactor with no fissionable material present. Any increase in neutron or ^{3}He output in the reactor that includes fissionable material that cannot be explained by any other mechanism may lend support to the hypothesis of antineutrino catalyzed fusion presented here.

Conclusion

It has been hypothesized that the nuclear fusion of Deuterium that has occurred in the fission-fusion hybrid hydrogen bomb was catalyzed by the antineutrinos emitted by the rapid beta decay of fission daughter products. A mechanism of nuclear fusion wherein an antineutrino and a positron are intermediates in the propagation of chain reaction has also been delineated. Methods of testing this hypothesis, both theoretically and experimentally, have been presented. While it is evident that presented mechanism does not fit within our current understanding of the behavior of neutrinos and antineutrinos, the author recommends that the ideas presented herein be subject to further theoretical and experimental analysis due to significant benefit that controlled nuclear fusion affords humanity.

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