Nuclear fusion as a virtual particle interaction analogous to Hawking radiation

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Abstract

Fusion interactions occur over a broad range of energies. Deuterium-Deuterium fusion for example has a peak cross section of hundreds of KeV, but fusion can occur below 20 keV. Efforts to increase fusion efficiency require higher interaction probabilities at lower energies. Efforts to do that are hampered by a lack of understanding of the physical mechanism that allows for lower energy nuclear reactions. While there is the idea of quantum-tunneling a more detailed model would be beneficial to the research effort. This paper will consider fusion reactions mediated by a Hawking radiation type interaction where a virtual proton-antiproton pair for example effectively annihilates a proton in one atomic nucleus and deposits a proton in another.

Introduction

A fusion reaction requires that two positively charged nuclei be brought together at high enough energy so that fusion can occur. In a classical view the amount of energy needs to be sufficient to overcome Coulomb repulsion, known as the Coulomb barrier. It has, however, been shown experimentally that fusion occurs at temperatures and energies far below those required to overcome the Coulomb barrier. It is thought that there is a quantum-tunneling phenomenon that allows for this. Once the particle, a proton or neutron, tunnels through the Coulomb barrier then the strong nuclear force takes over binding it to the nucleus completing the fusion reaction.

The experimental data shows a probability curve or interaction cross section where the peak reaction probability occurs at a high energy, but the reaction still occurs at far lower energies. For Deuterium-Deuterium (D-D) interactions the peak energy is greater than 300 keV, but fusion occurs at 20 keV and below, while for Deuterium-Tritium (D-T) interactions the peak energy is around 70 keV with efficient fusion still occurring at 10 keV an below. Designing a successful greater than breakeven fusion apparatus requires that it be highly efficient at the lower energies. In essence the tunneling mechanism must be made more efficient even as the energy is kept low or lowered.

At the lowest end of the energy spectrum are Low Energy Nuclear Reactions (LENR). In LENR experiments the fusible nuclei are held within a metal lattice such as palladium. The results of these experiments are under contention largely due to difficulties measuring small neutron fluxes. The method also suffers due to the lack of a generally accepted mechanism explaining the quantum tunneling between lattice bound nuclei.

The Hawking Fusion Interaction

Stephen Hawking hypothesized that a vacuum fluctuation, a virtual particle-antiparticle pair, near a black hole can be partly absorbed when one particle of the pair crosses the black hole event horizon leaving the other outside the event horizon where it may escape.[1] When that occurs the virtual particle pair does not recombine and consequently the escaping particle effectively causing the black hole to radiate energy. This mechanism is known as Hawking radiation.

We can similarly consider what happens when a vacuum fluctuation, consisting of a virtual proton-antiproton pair comes into existence between two adjacent deuterons. Since a vacuum fluctuation is electrically neutral when formed it may cross coulomb barriers or even form within the barrier. A virtual proton-antiproton pair can occur over a range of energies with a range of effective wavelengths, so it is possible for the virtual proton to cross the Coulomb barrier of one deuteron while the virtual antiproton of the pair crosses the Coulomb barrier of a second deuteron. This can occur over a wide range of distances. The antiproton can than annihilate with the proton in one deuteron leaving a neutron, while leaving the once virtual proton free where it can be captured by the second deuteron yielding helium-3. This thought experiment outlines the basic principle behind a Hawking type fusion interaction. The same interaction works in the case of D-T fusion.

We can also consider fusion interactions mediated by virtual neutron-antineutron pairs. In that case the neutron will join with a deuteron yielding tritium, while the antineutron reacts with the other deuteron annihilating its neutron and leaving behind a proton. A virtual neutron-antineutron pair can similarly moderate deuterium and helium-3 fusion yielding helium and a proton. Note that some fusion reactions require two essentially simultaneous Hawking interactions, but these are much less probable and generally require additional energy, as one might expect.

We can then consider LENR reactions. The crystal lattice spacing of palladium hydride is approximately 4 angstroms. This distance equates to the wavelength of a 1.55 keV virtual proton-antiproton pair. Probabilities of such interactions are likely very low, but should be non-zero, and should improve dramatically with small decreases in distance.

Conclusion

A Hawking interaction analogous to Hawking radiation yields a logical and intuitive mechanism to explain quantum tunneling in nuclear fusion interactions. Like Hawking radiation, half of a virtual particle pair is captured while the other becomes free. This results in a particle appearing to jump from one nucleus to another. This hypothetical interaction has essentially the same likelihood of being correct as Hawking's theory of radiation from a black hole and should aid us as we seek to improve the efficiency for all methods of fusion.

[1] S. Hawking, "Black hole explosions?" Nature 248, 30 (1974). doi:10.1038/248030a0