The Fusion Fuel Resource Base in our Solar System

Robert G. Kennedy III, PE [1]*
[1] Institute for Interstellar Studies-US, Oak Ridge, TN, USA

Abstract

If a self-propelled ship is going to get to another star in less than many millennia, humanity will need ***vast*** quantities of highly energetic fusion fuels. Even fission will not do the job. However, the five hydrogen fusion reactions that the human race knows about have major, engineering, energetics or logistics liabilities.

The most common reaction is the complicated multistep one going on inside our Sun now. In **proton+proton fusion**, stable helium-4 is generated one of four possible ways: This is the hottest reaction, hence hardest, so, ubiquitous as it is, we do not know how to replicate it artificially.

$$4p \to {}^4He + 2e^+ + 2\nu_e$$

Next is **deuterium+tritium fusion**. Being the coolest, it should be the easiest, but it has three major drawbacks—(1) *engineering*, right now we can only make bombs with this one; a breakeven, steady-state reaction has not been achieved—(2) *efficiency*, about ¾ of the total yield, ~14 MeV, is carried off by a useless fast neutron. Since they are charge-less, it is very difficult to harness neutrons. (3) *logistics*, the tritium has a half-life of only 12 years. Even for bombs, it has to be bred and replaced continually. For a centuries-long voyage, tritium is totally unsuitable.

$${}^2_1D + {}^3_1T \to {}^4_2He + {}^1_0n$$

Next is **deuterium+deuterium fusion**, with two flavors of equal probability:

$$D + D \to T + {}^1H$$
$$D + D \to {}^3He + n$$

The problem with D-D is that neutron coming off the second reaction. See issue #2 above.

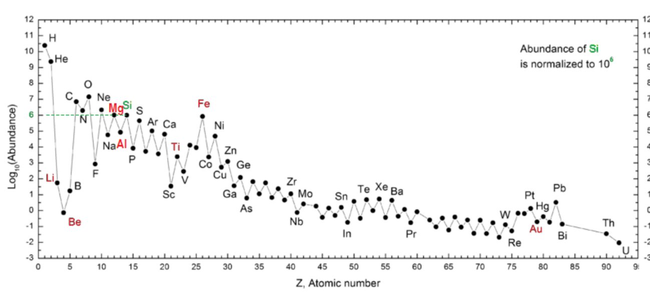
$$D + {}^3He \to {}^4He + {}^1H$$

Lunar advocates talk about **deuterium+helium-3 fusion**. No neutrons are made in the first stage and both reaction products can be ionized, therefore are harness-able in a reaction drive. But no one actually knows how to burn D-He3, and there are side reactions where the deuterons react with each other instead of the helium, producing useless neutrons. However, that's just an engineering problem. The main drawback is logistics: where are the necessary Gt of helium-3 per mission going to come from?

$${}^1H + {}^{11}B \to 3\ {}^4He$$

A neutron-free reaction is: **deuterium+boron-11 fusion**. All alphas mean high efficiency. Being a solid, the fuel is orders of magnitude more compact than liquid deuterium, which would make the ship a *lot* smaller. Boron-11 is the most common isotope, 80%. Trouble is, its abundance in the solar system appears to be down with rare earths, another logistics problem.

In 1983, William K. Hartman presented "Resource Base of the Solar System". I propose to repeat his approach 34 years later in order to estimate the human race's patrimony of easy fusion fuels. From this, I will estimate the total number of missions that could fly.



Keywords: Fusion Fuels, Resource Base, Solar System.

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*Corresponding author, robot@ultimax.com