Thorium Reactors vs. Fast Reactor Recycling of Slightly Used Nuclear Fuels

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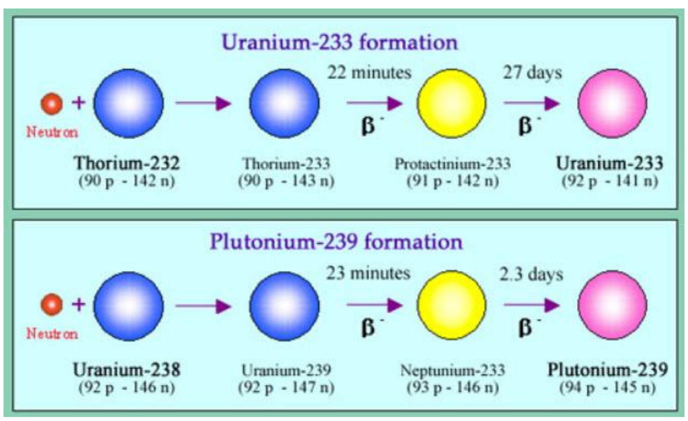
There is considerable discussion about extracting thorium from the ground and using it to generate electricity. This is a good idea, and the only problem we see is that there is more talk about it than action. So, if it is so great, just do it. However, there is a fuel similar to thorium that has already been mined and is stored in large quantities in our country. It seems beneficial to use this fuel as well for generating and distributing electricity. This fuel is known as Slightly Used Nuclear Fuel (SUNF) and is generated from light-water reactor power generation. Both fuels require two neutrons to initiate a fission event, unlike 'fissile" materials such as U-235 (with a half-life of 704 million years) and some Pu-239 (with a half-life of 24,110 years), which need only a single neutron. Fortunately, more than two neutrons are produced in fission events, so with proper engineering, both "fertile" fuels (U-238 and Th-232) are practical for use in a fission reactor. They work by creating (activating) U-238 or Th-232 through neutron absorption. This process produces U-239 and Th-233, respectively. Through nuclear decay, these isotopes become Pu-239 (24,110 a) and U-233 (159,200 a). Each of these isotopes will fission if they absorb another fast neutron, generating energy that the reactor converts to electricity. Even though the neutron absorption cross sections for Pu 239 and U 233 are 100 times larger for thermal neutrons (slow neutrons, about 0.025 eV), the amounts of fissile materials and geometry more than compensate for this difference when using fast neutrons (about 1 MeV).[i]

What are the differences between using Thorium and SUNF?

Primarily, thorium can be used with either fast or thermal (light-water) neutrons. SUNF is more feasible with fast reactors. The decay chain of Th-233 is Pa-233 to U-233. The decay chain of U-239 is Np-239 to Pu-239. However, one issue arises from the half-life differences of Pa-233 and Np-239. Pa-233 decays with a half-life of 27 days, while Np-239 decays with a half-life of 2 days. This means that it takes longer for U-233 to build up in a thorium reactor than for Pu-239 in a fast reactor. If many neutrons are lost to Pa-233 absorption, fewer neutrons will be available to fission U-233 and produce energy. The loss of neutrons to Np-239 in a fast reactor is at least ten times less than to Pa-233 in a thermal reactor. This may require separating Pa-233 from the fuel mix and allowing it to decay to U-233 before it can be used for power generation.



Therefore, the design of reactors must maximize breeding (adding neutrons to U-238 and Th-232) and burning (fissioning Pu-239 and U-233) efficiency. While both are feasible and have been demonstrated in experimental reactors, U-238 has the advantage of recycling existing SUNF stockpiles to produce at least 30 times the energy originally generated by the light-water reactor that produced the SUNF.

A major advantage of thorium reactors is that they can give a useful purpose to thorium, which is a contaminant in rare earth mining. Such a beneficial use could make separating thorium profitable and make rare earth mining ventures more profitable. The decision is which technology can compete to produce cheap, abundant electricity. Both offer the essentially unlimited supply needed to power modern societies. Both can scale reactors over a wide range, even into the multiple GW range. Both support high heat operations, which provide advantages of greater efficiency in electricity generation and the ability to supply high heat directly to industrial processes (compared to burning coal to reach these heat levels). Each technology benefits from privately capitalized companies in the US that are working toward commercial viability.

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[i] For Pu 239, the thermal neutron fission cross section is about 400 times larger than for fast neutrons, and for U 233, it is about 200 times larger. Therefore, the thermal neutron fission cross section of Pu 239 is approximately 50% greater than that of U 233.