ARE RADIATION-FREE NUCLEAR REACTIONS POSSIBLE?

One of the advantages of nuclear fusion energy is the reduced radioactivity as compared with fission-based power systems. During the past year, however, there has been speculation that fusion reactions might be found that are totally (or nearly totally) free of harmful radiation.

The well-known reactions between two deuterium (a heavy-hydrogen isotope) nuclei,

Deuterium + Deuterium $\rightarrow$ Helium 3 + Neutron + Energy

and

Deuterium + Deuterium $\rightarrow$ Hydrogen + Tritium + Energy,

yield highly energetic alpha particles (helium nuclei), neutrons, and protons (hydrogen nuclei). In connection with the highly speculative research on room-temperature electrochemical fusion (cold fusion), several researchers have proposed a reaction channel,

Deuterium + Deuterium $\rightarrow$ Helium 4 + Energy,

where it is assumed that the energy is distributed throughout a solid-state lattice. If the reaction energy can be distributed over a large enough number of nearby nuclei, then no single particle needs to be highly energetic. That is, there doesn't need to be any dangerous "radiation." The nuclear force responsible for fusion reactions has a large magnitude ($F \sim 10^3$ N) and a very short range ($d \sim 10^{-15}m$). Because of its short range, the nuclear force can act on only a very few neutrons or protons, each of which has a very small mass ($m \sim 10^{-27}$kg). Such a strong force will move these small masses through this tiny distance in a time of the order of $10^{-22}s$, namely,

$$F = ma, \quad d = \frac{1}{2}at^2, \quad t = \frac{2dm}{F}, \quad t \approx 10^{-22}s.$$

Thus we estimate that typical nuclear reactions will occur in about $10^{-22}s$.

We know, however, that energy cannot be propagated faster than the speed of light, $c = 3 \times 10^8$ m/s. Therefore, the reaction energy is distributed over a very small distance ($D$) of, at most, a fraction of $10^{14}$ meter,

$$D = ct \approx \text{few x } 10^{-14}m.$$

This distance is much smaller than the dimensions of a single atom. The energy resulting from the fusion reaction cannot be distributed over a large enough number of atoms to dissipate it, and radiation must result. An energy source that is nuclear in nature must, then, necessarily produce some detectable radiation!

Robert Jones, Professor
Physics Department
Division of Physical Sciences
Emporia State University