An Enhanced Reactor

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The possibility of using a thermal uranium reactor to induce secondary fusion reactions is examined. Deuterons and tritons are accelerated by collisions with neutrons and fission fragments and the resulting $D-T$ reactions are calculated to yield 10^{-3} neutron per fission.

IN order to produce useful particles or energy from light element fusion, it is necessary to accelerate the nuclei in some fashion so that the reaction probability reaches some reasonable value. Two methods of doing this are (1) the ordinary laboratory procedure of electrically accelerating particles to high energies, and (2) the use of some high temperature trigger reaction, such as an atomic bomb, to raise the macroscopic temperature of the light nuclei to the point where their mutual reaction cross section becomes appreciable.

A third possibility, not previously mentioned, is the use of a thermal uranium reactor to induce secondary light element reactions on a controlled basis. If the kinetic energy of the recoiling fission fragments and fast neutrons can be used to accelerate some light nuclei, then a secondary reaction is possible which would release additional energy and neutrons.

The preliminary scheme studied consists of a thermal uranium reactor with enriched U^{235} as a fuel and a mixture of deuterium and tritium as a moderator. The actual composition of the moderator is not specified; however, the hydrogen density has been assumed to be the same as in water. In such a reactor the optimum hydrogen-uranium ratio is about 600:1, so that in a homogeneous reactor each uranium atom is effectively surrounded by hydrogen atoms. To a first approximation such a chain reaction will proceed in a normal manner, with the hydrogen (H^2 and H^3) merely slowing down the fission neutrons by elastic collisions and the only energy release being from the direct uranium fissions.

If the reactions are examined in greater detail, it is seen that deuterons and tritons will be accelerated by collisions with the fission fragments and fast neutrons and, as accelerated particles, can react in a $D-T$ reaction releasing energy and neutrons. These possible reactions have been examined in order to obtain some quantitative estimate of their importance.

Fission fragments slow down by two distinct processes. The first is by electronic excitation and ionization of the moderator atoms and the second is by nuclear collisions. According to Bohr's theory of fission fragment energy loss,[1] the first process is the dominant one until the fragments have slowed down to a velocity equal to the electronic velocity of the most loosely bound electron in the atomic shell. This is approximately 2.2×10^8 cm/sec and corresponds to an energy of 2.4 Mev for the light fission fragment of mass 95 and initial energy 97 Mev. After this energy is reached the fission fragment reactions with the electronic cloud are primarily adiabatic and the energy loss mechanism becomes the elastic nuclear collision process. For the light fragment colliding with tritons, the average energy loss per collision is 0.059. By calculating this series of collisions, multiplying by the appropriate cross section[2] and integrating, the total yield of secondary neutrons is found to be 0.97×10^{-4} neutrons/fission fragment.

The slowing down of the fission neutrons takes place only by elastic collisions (ignoring possible inelastic collisions) and there is no electronic collision term to be calculated. The elastic collisions result in an average loss per collision with tritons of 0.375. Assuming an average fission neutron energy of 2.3 Mev at birth, this series of collisions is calculated and operated upon in the same fashion as the fission fragment collisions. The net result is a total yield of 3.25×10^{-4} neutron/fission neutron. Summing these yields for the two fission fragments and the 2.5 neutrons per fission gives a total yield of 1×10^{-3} neutron/fission.

Although this is a rather small increment to the uranium chain reaction, it is not an impossible line of development. The calculations are admittedly rough and might be in error by an order of magnitude. There may be some method of developing a very high localized temperature which would increase the reaction cross section. There may be some alternative accelerator-induced reaction which would yield high energy fragments or neutrons by fission or spallation, thus giving higher yields. Finally, there may be other reactions than the $D-T$ one with more favorable yields at the energies considered.

[1] N. Bohr, Phys. Rev. **58**, 654 (1940).
[2] Hanson, Taschek, and Williams, Revs. Modern Phys. **21**, 635 (1949).