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Theory of Low-Temperature Particle Showers

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Abstract

A theoretical basis is offered for the remarkable observation by Oriani and Fisher [1] of a shower of about 250,000 energetic charged particles that occurred in the vapor of oxygen and hydrogen evolved from electrolysis. The shower was localized in space and in time, originating a few millimeters above the surface of a plastic detector chip and lasting for a few seconds. The responsible nuclear reactions must have been sustained by the vapor constituents.

I. THEORY

The theory assumes that neutron aggregates (variously termed neutron isotopes, polyneutrons, or neutron droplets), of size exceeding about six neutrons, are bound and stable against strong decay. A portion of the binding energy is assumed to arise from attractive neutron pairing analogous to the electron pairing in superconductivity, and does not reach its full strength until the droplet size reaches a coherence volume of twenty or so neutrons. Weaker binding for smaller droplets accounts for the gap of instability below about eight neutrons. Accepting that bound neutron isotopes exist, the table of isotopes expands to include droplets with tens, hundreds, or thousands of neutrons, all stable against strong decay and with lifetimes determined by the rate of beta decay in which a neutron transmutes to a proton plus an electron and an antineutrino.

We consider two classes of reactions between polyneutrons and ordinary nuclei. In one class a polyneutron donates one or more neutrons to an ordinary nucleus or it accepts one or more neutrons from an ordinary nucleus. These reactions can have extremely large cross sections because there is no coulomb barrier for approach of reactants or for separation of products. In the other class of reactions a polyneutron binds with an ordinary nucleus to form a halo nucleus where the ordinary nucleus dissolves in the polyneutron. Binding energy is provided by a reduction of surface energy of the ordinary nucleus. Halo nuclei are stable against strong decay provided that all potential exchanges of neutrons between the halo and the ordinary nucleus at its core are endothermic. This limits the number of potential core nuclei to particularly stable nuclei including ^{4}He, ^{12}C, and ^{16}O. Symbolically halo nuclei are written with the core and halo components adjacent to each other as for example $^{16}O^{A}n$ for a nucleus with core ^{16}O and halo ^{A}n.

The theory suggests that a single polyneutron can ignite a chain reaction that is sustained by ^{18}O as fuel. Polyneutrons grow two neutrons at a time as they interact with ^{18}O to form ^{16}O,

$$^{A}n + {}^{18}O \rightarrow {}^{A+2}n + {}^{16}O. \tag{1}$$

When large enough they fission in interaction with ^{18}O and increase the number of polyneutrons in the chain,

$$^{A}n + {}^{18}O \rightarrow {}^{B}n + {}^{C}n + {}^{16}O^{A-B-C+2}n \tag{2}$$

where one of the products is the halo nucleus $^{16}O^{A-B-C+2}n$ with an ordinary nucleus ^{16}O dissolved in the neutron droplet $^{A-B-C+2}n$. Halo nuclei with ^{16}O and ^{12}C cores can interfere with the chain reaction by shrinking or capturing polyneutrons,

$$^{A}n + {}^{16}O^{B}n \rightarrow {}^{A-C}n + {}^{16}O^{B+C}n \tag{3}$$
$$^{A}n + {}^{18}O \rightarrow {}^{12}C^{A+2}n + {}^{4}He. \tag{4}$$

The binding energy of the halo nucleus $^{12}C^{A+2}n$ provides an increment of energy that makes reaction (4) exothermic.

For chain reactions in the bubble-growth regions near electrodes during electrolysis, rapid shear deformation of the fluid removes halo nuclei from the reaction volumes and allows chain reactions to continue at a bounded rate. New reactions then can be initiated, in quiescent electrolyte and in the vapor, by emission of polyneutrons in a rare decay channel from halo nuclei generated in the ongoing reactions near electrodes,

$$^{16}O^{A}n \rightarrow {}^{12}C^{A-X-Y}n + {}^{4}He^{Y}n + {}^{X}n. \tag{5}$$

But reactions in quiescent regions are soon brought to a halt as free polyneutrons are captured by the buildup of halo nuclei in reactions such as (3) and (4).

Halo nuclei then decay by successive beta and alpha decays that provide most of the energetic particles in a shower,

$$^{16}O^{A}n \rightarrow {}^{16}O^{A-4}n + {}^{4}He + 2\,e^{-} + 2\bar{\nu} \tag{6}$$
$$^{12}C^{A}n \rightarrow {}^{12}C^{A-4}n + {}^{4}He + 2\,e^{-} + 2\bar{\nu}\,. \tag{7}$$

In the vapor phase such shower particles have sufficient range to register on nearby plastic detectors. In this way we can understand the shower that was observed in the vapor over an active electrolysis cell [1].

[1] R. A. Oriani and J. C. Fisher, "Energetic charged particles produced in the gas phase by electrolysis", Proc. 10th Int. Conf. Cold Fusion (2003).