Muon Catalyzed Fusion And Fusion With Polarized Nuclei

Two alternative methods have been suggested to produce fusion power at low temperature. The first, muon catalyzed fusion or MCF, uses muons to spontaneously catalyze fusion through the muon mesomolecule formation. Unfortunately, this method fails to generate enough fusion energy to supply the muons, by a factor of about ten. The physics of MCF is discussed, and a possible approach to increasing the number of MCF fusions generated by each muon is mentioned. The second method, which has become known as Cold Fusion, '' involves catalysis by electrons in electrolytic cells. The physics of this process, if it exists, is more mysterious than MCF. However, it now appears to be an artifact, the claims for its reality resting largely on experimental errors occurring in rather delicate experiments. However, a very low level of such fusion claimed by Jones may be real. Experiments in cold fusion will also be discussed.

Some topics in muon-catalyzed fusion theory are discussed: Resonant formation of dd[mu] molecules appears to be well understood, with good agreement so far between theory and experiment. The situation for resonant dt[mu] formation is much less clear, because of the more complicated kinetics, the apparent three-body effect, and the evident need to treat thermalization and molecular formation together to compare theory and experiment. Recent theoretical progress in pd[mu] fusion by Friar et al. has resolved a serious discrepancy in the Wolfenstein-Gershtein effect, i.e., the increase in pd[mu] fusion yield with increased deuterium fraction. 44 refs., 8 figs., 2 tabs.

The International School of Fusion Reactor Technology started its courses 15 years ago and since then has mantained a biennial pace. Generally, each course has developed the subject which was announced in advance at the closing of the previous course. The subject to which the present proceedings refer was chosen in violation of that rule so as to satisfy the recent and diffuse interest in cold fusion among the main European laboratories involved in controlled thermonuclear research (CTR). In the second half of 1986 we started to prepare a workshop aimed at assessing the state of the art and possibly of the perspectives of muon-catalyzed fusion. Research in this field has recently produced exciting experimental results open to important practical applications. We thought it worthwhile to consider also the beneficial effects and problems of the polarization ofthe nuclei in both cold and thermonuclear fusion. In preparing the 8th Course on Fusion Reactor Technology, it was necessary to abandon the traditional course format because the influence of the workshop procedure was inevitable: the participants were roughly equally divided into experts in cold fusion and experts in thermonuclear fusion. The course had largely an interdisciplinary character as many disciplines were involved: atomic and molecular physics, nuclear physics, accelerator technology, system analysis, etc. Plasma physics was excluded, with a sigh of relief from the experts in thermonuclear fusion.

Muon-Catalyzed Fusion and Fusion with Polarized NucleiSpringer Science & Business Media

The effect of resonance nuclear fusion reaction on the initial muon sticking factor is formulated. The analysis shows that it is very sensitive to the resonance parameter, and the factor calculated, using the molecular wave function obtained by the Diffusion Monte Carlo method, is 0.1 +- 0.01 for the presently evaluated resonance parameter. The analysis of the multistep excitation effect on the reactivation factor shows that the effect is not so large, and the analysis of muonic x-ray spectra of .mu.3He from P.mu.d and d.mu.d fusions is in good agreement with the values measured by Bossy et al.

Two important stages in the kinetics of muon-catalyzed d-t fusion are discussed: (1) atomic thermalization and hyperfine-state relaxation preceding molecular formation and (2) muon stripping and x-ray production if sticking occurs after nuclear fusion. Thermalization is accurately treated by Monte Carlo simulation. It is shown that thermalization and triplet quenching of the .cap alpha mu. atom may not finish before dt.mu. formation in low-tritium targets, but that epithermal transients are most important in high-tritium targets. A complete kinetic treatment of muon stripping from .cap alpha mu. is made using newly calculated stripping (ionization and charge transfer) and inelastic excitation cross sections and explicitly treating the 2s-2p Stark mixing. The calculated values of the sticking probability and K.cap alpha. .cap alpha mu. x-rays per fusion are .omega./sub s/ = 0.53% (0.59%) and I/sub K.cap alpha.//chi = 0.23% (0.28%) at density phi = 1.2 (0.1) times liquid-hydrogen density. Sensitivities to the various kinetic rates are evaluated, and error bars are estimated.

The main steps in the muon-catalyzed d-t fusion cycle are given in this report. Most of the stages are very fast, and therefore do not contribute significantly to the cycling time. Thus at liquid H/sub 2/ densities (/phi/ = 1 in the standard convention) the time for stopping the negative muon, its subsequent capture and deexcitation to the ground state is estimated to be /approximately/ 10/sup/minus/11/ sec./sup 1/ The muon spends essentially all of its time in either the (d.mu.) ground state, waiting for transfer to a (t.mu.) ground state to occur, or in the (t.mu.) ground state, writing for molecular formation to occur. Following the formation of this "mesomolecule" (actually a muonic molecular ion), deexcitation and fusion are again fast. Then the muon is (usually) liberated to go around again. We will discuss these steps in some detail. 5 refs., 3 figs.

Muon-catalyzed fusion ([mu]CF) has proved to be a fruitful subject for basic physics research as well as a source of cold nuclear fusion. Experiments have demonstrated that over 100 fusions per muon can be catalyzed by formation of the dt[mu] molecule in mixtures of deuterium and tritium. After a brief review of the subject's history, the dt[mu] catalysis cycle and the principal relations used in its analysis are described. Some of the important processes in the [mu]CF cycle are then discussed. Finally, the status of current research is appraised. 52 refs., 7 figs.

"An analysis of the energy economy of a theoretical muon-catalyzed nuclear fusion system has been made by invoking the use of point kinetic equations, Monte Carlo radiation transport simulations, and from a review of existing literature on muon-catalyzed fusion. An external X-ray reactivation source is proposed as a novel way to increase the number of fusions per muon and thereby overcome the so-called alpha sticking problem that has long been considered the primary impediment to breakeven muon-catalyzed fusion power. Free electron lasers, synchrotrons and Wakefield accelerators are discussed as possible bright X-ray photon sources. The addition of an intense external reactivation source into a deuterium-tritium medium can greatly increase the fusion rate per muon. However, energy breakeven analysis shows that the energy density of a power producing system would need to reach unrealistically high levels in order to maintain the energy cost of the external reactivation source. Thus, external reactivation is not a practical approach to muon-catalyzed fusion"--Abstract, page iii.

A brief summary of results during this report period is given. Some of the topics investigated includes: (1) calculations of sticking fractions and d-t fusion from dt[mu](JV) states, (2) dd[mu] sticking fractions, (3) the reactivation coefficient in d-t fusion, (4) fusion rates for all XY[mu](JV)(JV=0,1), (5) nuclear effects on energy shifts and fusion rates for (J=O) states of dt[mu], (6) and some comments on cold fusion.