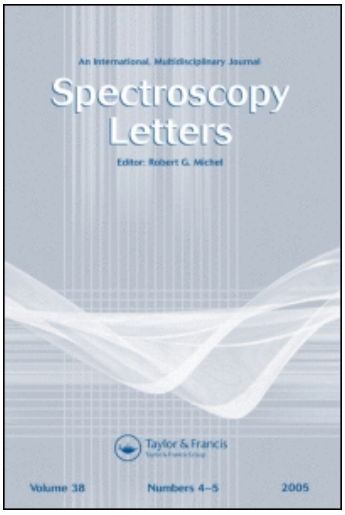

Spectroscopy Letters
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597299

Chemistry in Lasers. XII. Energy Release Considerations with Special Emphasis on Nuclear Fusion of Isotopic Boron Hydrides

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To cite this Article Keszthelyi, Csaba P.(1978) 'Chemistry in Lasers. XII. Energy Release Considerations with Special Emphasis on Nuclear Fusion of Isotopic Boron Hydrides', Spectroscopy Letters, 11: 3, 213 — 219
To link to this Article: DOI: 10.1080/00387017808067746
URL: http://dx.doi.org/10.1080/00387017808067746

SPECTROSCOPY LETTERS, 11(3), 213-219 (1978)

CHEMISTRY IN LASERS.XII. ENERGY RELEASE CONSIDERATIONS WITH SPECIAL EMPHASIS ON NUCLEAR FUSION OF ISOTOPIC BORON HYDRIDES

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KEYWORDS: boron isotopes, boron hydrides, nuclear fusion

ABSTRACT

A two-step controlled nuclear fusion process utilizing doubly-isotopic boron hydrides (H-2 or H-3 combined with B-11), optionally driven by an e-beam/laser combination, is presented as an optimal approach for energy release via laser driven fusion. Among the large number of possible compounds, B_4H_{10}, B_5H_{11}, B_9H_{15} are listed as suitable analogs, while it remains feasible to select compounds with varying mass ratios of the desired isotopes. In the process primarily laser driven heavy hydrogen fusion is used as initiator for the more economical boron-11 fusion. The optional auxiliary technique, in itself a noteworthy process due to the combination of the e-beam and laser excitation, is of special significance in this case because of the electron deficient nature of the pellet com-

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pounds, whose topological properties are indicative of inertial confinement time improvements. No new experimental data on fusion is presented.

Since the first extended report (1) in 1933 on the class of compounds known as boron hydrides, some of the most exciting developments in chemistry have been tied to this area of research, and in a sense it would be appropriate if a breakthrough in the vastly important energy problems of our day were to come from this field also. A few topics deserve mention as particularly relevant within the present context, even though by no means do we intend to attempt to give a worthy review of the development of boron chemistry on these pages. Perhaps the most widely appreciated peculiarity of boron chemistry is the 'electron deficiency' of some compounds like B_2H_6, or icosahedral fragments; this leads to the three-center bond concept (2-4) which enjoys general acceptance today. The charge distribution can be approximated in a simple manner from atom-atom polarizability (Π (k,l)) as:

$$\Pi(k,l) = 2 \sum_{j=1}^{m} \sum_{i=m+1}^{n} \frac{C_{lj} C_{li}}{\epsilon_j - \epsilon_i} \left[C_{kj} (SC)_{ki} + C_{ki} (SC)_{kj} \right], \quad [1]$$

where ϵ_i represent zeroth-order energies, and all levels are empty except those below n, which are doubly occupied. It is of particular interest to us that negative charges tend to be localized in the inner regions of the molecule, and in most cases with disruption of the molecular geometry. This suggests the possibility of highly inelastic interactions with e-beams, due to the availability of very

long duration reaction channels (i.e., molecular rearrangement). Some of these rearrangements are also significant in terms of the resurgence of chemical topology in the last few years; the pioneering work of early investigators (5) has never been extended to high energy density regions which are of fundamental concern in this series, and it is hoped that some effort in basic research will be devoted to this area of boron chemistry in the near future.

There are two main experimental approaches available to achieve controlled nuclear fusion, which in turn offers useful energy release. Considerations of a charged particle accelerator, representing one approach, are reserved for later on, except that it is useful to point out at this stage the essential contrast between it and thermonuclear fusion: accelerated particles comprise a rather uniform vectorial ensemble with respect to both direction and energy, whereas in the thermonuclear approach the ensemble is normally characterized by a wide distribution of energies as well as random motion. It may also be recalled that it is necessary to distinguish, in the thermonuclear approach, between a kinetic temperature related to Maxwellian distribution, and an equivalent-radiation temperature based on black body radiation; the significant differences between the two temperatures can, in the broad sense, provide the philosophical framework that characterizes fusion research, the perhaps perultimate challenge that has attracted many leading scientists in recent years. An additional item worthy to mention is the discrepancy between the Coulomb barrier calculated according to classical theory, and the experimentally observed barrier penetration (which accounts for the

fact that nuclear reactions do occur at detectable rates far below the Coulomb barrier, and provides perhaps a most powerful argument in favor of quantum mechanics and tunneling.) Beyond these remarks it would be counterproductive to try to review within this brief space the development of hydrogen isotope based fusion, an area of chemistry so well established in recent years that even elementary texts cover it in considerable detail (6). Summarizing some of the heavy hydrogen reactions, including the "neutron branch" (Eq. 2), the "proton branch" (Eq. 3), and two reactions (Eqs. 4 and 5)of high energy yield:

$$D + D \rightarrow He^3 \underset{(0.82\ MeV)}{} + \underset{(2.45\ MeV)}{n} \quad (2)$$

$$D + D \rightarrow T \underset{(1.01\ MeV)}{} + \underset{(3.02\ MeV)}{H} \quad (3)$$

$$D + T \rightarrow He^4 \underset{(3.5\ MeV)}{} + \underset{(14.1\ MeV)}{n} \quad (4)$$

$$D + He^3 \rightarrow He^4 \underset{(3.6\ MeV)}{} + \underset{(14.7\ MeV)}{H} \quad (5)$$

we find that about 33% of the energy liberated is carried by charged particles to be deposited internally within the reacting system for a pure deuterium target, with the neutrons making additional contributions. This internal energy would aid, in a laser driven arrangement, the next stage: fusion involving boron nuclei.

The complete-fusion cross section of boron-11 + terbium-159 was reported by Kozub et. al. (7) in 1974, while Zebelman and

co-workers reported (8) in the same year both fission and complete-fusion values. Evidence of an intermediate quasistationary state in boron-11 fusion was presented (9) by Petkov et. al. in 1975, and related by the same authors to fission calculations in a separate publication (10). While only a fraction of the boron fusion effort has been fully reported, several important advances are documented for the year 1976: (a) Dayras, Stockstad, Switkowski and Wieland at CIT determined fusion cross sections for B + ^{12}C over a 5 MeV range extending below the Coulomb barrier, and compared the results with optical model calculations (11); (b) Namboodiri and co-workers examined fusion products of ^{12}C + ^{12}C, and considered the boron cross section also (12); (c) Datla et. al. used a small θ-pinch plasma to deduce ionization rate coefficients for B (IV) as well as C (V) (13). Because the main goal of the present work is to call attention to a two-step fusion process involving isotopic boron hydrides, not all relevant considerations necessary to develop a complete operational system are covered, even in a tentative fashion. It is important, however, to discuss the future trend of departing from gas dynamic ablation models in using laser excitation -- this is deemed by the present work to be a development comparable with some of the fundamental impact advances/discrepancies cited earlier in the paper. Up to 50% of the laser energy is transferable into pellet kinetic energy by dynamic absorption and superefficient compression, as was shown by Hore (14) of the Max Planck Institute for Plasmaphysics recently. The key concept in Hore's approach is to avoid conditions that hamper cold implosion. The structural-

topological changes feasible with boron hydrides, optionally brought about or facilitated by e-beam impact, offer a suitable framework for a concerted experimental inquiry.

In conclusion we should emphasize that the authoritive text for energy release via controlled nuclear fusion has not been written yet, and the preceeding considerations at best may serve as a footnote in it. The formulation of authoritive new theories often follows conspicuous experimental findings, and this may be exceptionally true for a subject as complex as the one raised here. The extrapolation of a Bonhoeffer oscillator (15) from ordinary laboratory conditions to extraordinary energy density situations is a rather tenuous one; at the same time it would be of immense utility (16). While pellet performance, with its chemical ramifications, deserves increased attention, high-power small λ excitation sources may be of great complementary value. We plan to develop the present topic in a continuation to the series, dealing with noble gas hydrides as laser materials, and some of their advantages over rare gas halides and dimers.

Acknowledgement. Presented in part at the 51-st Annual Meeting of the Louisiana Academy of Sciences (Shreveport, Louisiana, Feb. 4, 1977).

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Editorial Date: 27 FEB 77