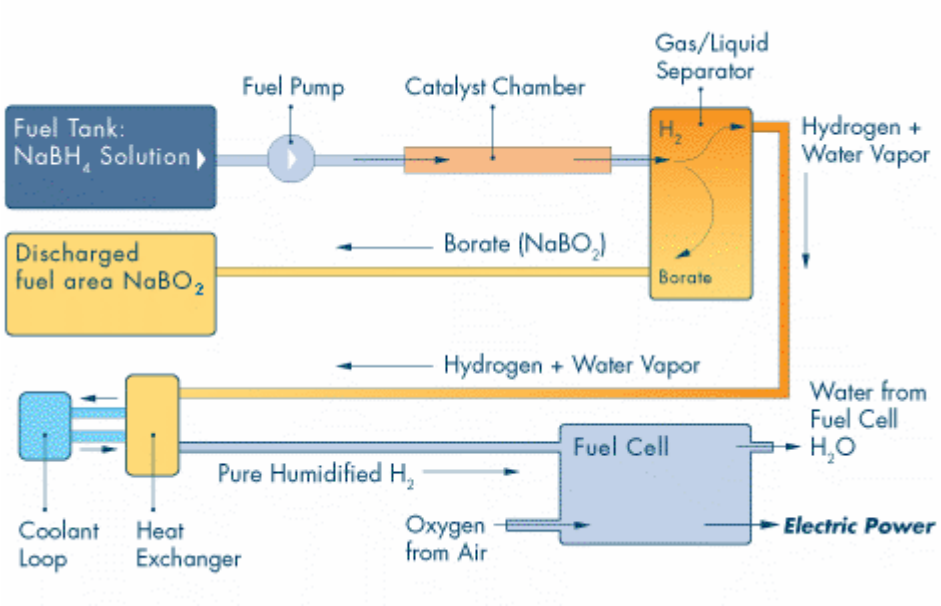
BO to BH Conversion

Boron-hydrogen compounds are being investigated as chemical hydrogen storage media. In particular, we are working with the compound sodium borohydride, *$NaBH_4$*, which contains 10.5% hydrogen by mass. Sodium borohydride may undergo hydrolysis, releasing very pure hydrogen gas:

$$NaBH_4 + 2H_2O \rightarrow 4H_2 + NaBO_2$$

When stored in alkaline, aqueous solution, the sodium borohydride decomposes very slowly. This solution is neither flammable nor explosive. To release the hydrogen gas, the solution is pumped through a catalyst. This means hydrogen gas can be produced as needed; clearly, this is a great advantage for safety and for mobile applications (automobiles). One of our corporate partners, Millennium Cell, has patented a technology based on this reaction, called Hydrogen on Demand ®:



Source: http://www.millenniumcell.com/fw/main/How_it_Works-31.html

A major obstacle to wider use of sodium borohydride as a hydrogen storage medium lies in its cost. The current industrial route to sodium borohydride produces a large quantity of by-products and uses a lot of electrical energy, making its efficiency low. Consequently, other synthetic methods are being investigated for producing sodium borohydride from borate or metaborate ion. Of great interest is the development of methods for "on-board" regeneration of *BH_4^-* with minimal operator intervention and within a closed cycle system

Our part of the project is in researching alternate routes from sodium borate or metaborate to sodium borohydride from borate or metaborate anion. The emphasis is on recycling of the *$NaBO_2$* by-product from the hydrolysis reaction via electrochemical and hydrogen plasma reduction routes. The patent literature indicates that electrochemical methods have been

explored as means of reducing borate or metaborate ion to borohydride. However, attempts to reproduce the claims of several of these patents have generally failed (1). Our recent work has identified the kinetic barrier to the conversion of BO_2^- to BH_4^- and strategies have been devised to overcome the barriers.

Hydrogen plasma reduction of borate or metaborate compounds does not appear to have been studied in the past. A hydrogen plasma contains highly energetic species, such as atomic hydrogen and protons, in addition to electrons; species that we believe are important in the production of sodium borohydride from borate or metaborate compounds. Consequently, we are also studying hydrogen plasmas as a means of reducing borate or metaborate compounds.

As an academic center for research, we are also carrying out fundamental studies to elucidate the mechanism of any promising routes we discover. With mechanistic information, we can identify the slow steps and possibly apply catalysis to enhance yields and decrease the energy expense of the process.

In addition to working with Millennium Cell, we also collaborate with Rohm and Haas and Los Alamos National Lab (LANL). We would like to acknowledge DOE for funding our research [Award DE-PS36-03GO93013], Rohm and Haas for providing $NaBH_4$ for our experiments, and the valuable technical advice provided by Drs. Bill Tumas and Tony Burrell of LANL.

Sources:

(1) E.L. Gyenge and C.W. Oloman. *J. Appl. Electrochem*. **28** 1147 (1998).

Websites to visit for more information:

(1) http://www.millenniumcell.com/fw/main/How_it_Works-31.html. This site describes how Millennium Cell's technology works.

(2) http://www.eere.energy.gov/hydrogenandfuelcells/storage/chem_storage.html. This site covers DOE chemical hydrogen storage research activities.

(3) http://www.hydrogen.energy.gov/pdfs/progress05/vi_b_4_tumas.pdf. This is a year-end progress report on research in chemical hydrogen storage from DOE-funded centers such as Penn State University.

(4) http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/review_chemical_processes.pdf. This document reviews methods that have been studied in attempt to produce sodium borohydride. A valuable list of references is included at the end.

For more information, please contact Digby D. Macdonald.