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Hydrogen production and storage from hydrolysis of sodium borohydride: study of the regeneration of sodium borohydride

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Abstract

Hydrogen is one of the most valuable alternatives to fossil fuels as an energy carrier. Although it is abundant in the universe and has the highest gravimetric density, it is not present in its molecular form. For this matter, it is typically stored in high pressure or cryogenic temperature tanks [1], which are not ideal solutions for decentralized energy generation. One alternative to these storage methods is to use the high hydrogen content of sodium borohydride (10.66 wt. % [2]) which allows to simultaneously produce and store hydrogen [1]. Hydrogen can be obtained at room temperature and pressure by hydrolysis of sodium borohydride, as described in Equation 1. For these reasons, it can be the solution for decentralized clean energy generation, providing energy to supply no-grid locations and to use in small portable applications.

$$NaBH_4 + (2+x)\ H_2O \rightarrow NaBO_2 \bullet\ x\ H_2O + 4\ H_2 \tag{1}$$

In Equation 1, x represents the hydration factor. Excess of water is necessary since the by-product of reaction, sodium metaborate, retains typically 2 or 4 water molecules, decreasing the hydrogen yield and generation rate [2]. Higher x allows the increase of the yield and generation rate; however, the gravimetric and volumetric hydrogen storage capacities decrease significatively. This is one of the main issues to the use of this chemical hydride to generate energy. Furthermore, the other problem associated is the cost of the sodium borohydride. It is therefore essential to regenerate the hydride from the by-product of hydrolysis.
Additives, for example sodium carboximethyl cellulose (CMC), can be added to the hydrolysis reaction to modify the chemical structure of the by-product. Ferreira et al. [3] observed the rearrangement of the sodium metaborate molecules when additive CMC was used in the hydrolysis of sodium borohydride. Thus, sodium boron hydroxide was formed, a compound that does not retain water molecules and it is easier to recycle than sodium metaborate. Overall, this work focuses on the study of the methods of regeneration of sodium borohydride from the by-product obtained in its hydrolysis. A comparison will be made between the main methods of production - Brown and Schlesinger and Bayer processes - and the *green* alternative – the modified Bayer process. Moreover, an electrochemical method to regenerate sodium borohydride will be demonstrated. If the regeneration of sodium borohydride is achieved, the implementation of a circular economy in a system that aims the production of *green* hydrogen for energy applications is possible.

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