Evaluation of Hydrogen Production Rates in Aluminum-based Water Splitting

Student

Rachel Anne Freeman

Definition of Task: Hydrogen will be an important carbon-free fuel source in the future. Renewable and carbon-free sources of hydrogen are important to reduce the environmental impact energy consumption. Currently, methane reforming is the most common hydrogen source. One novel approach to hydrogen production is the exothermic aluminum-based water splitting reaction. In the presence of water, aluminum will react to form aluminum hydroxide and hydrogen. Through recycling of aluminum byproducts, the process can become a renewable source of hydrogen. Production of hydrogen from aluminum and water can be produced on an as-needed basis, which reduces the need high volume and pressure storage. It also offers a safe and compact storage medium.

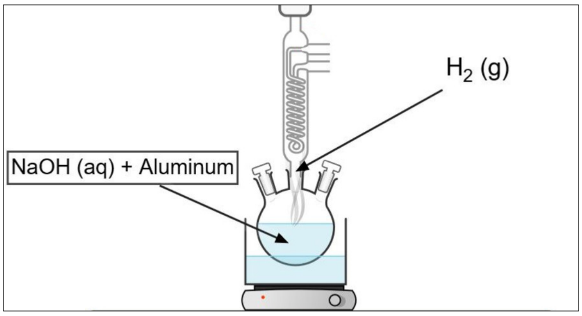
This study supports the larger project to develop a combined heat and power reactor based on the aluminum-based water splitting reaction Aluminum and water do not spontaneously react in everyday use due to a protective aluminum oxide layer. A hydroxide promoter is required to remove the protective layer on the aluminum and allow the reaction to progress. In order to support development of a combined heat and power reactor based on this reaction, the reaction parameters, mechanisms and products need to be fully defined. In the course of this project the following goals have been set:

1. Study and quantify the effect of reaction parameters such as temperature, hydroxide promoter concentration, salt promoters and aluminum structure
2. Recommend reaction conditions
3. Analyze the reaction products
4. Define the reaction model.

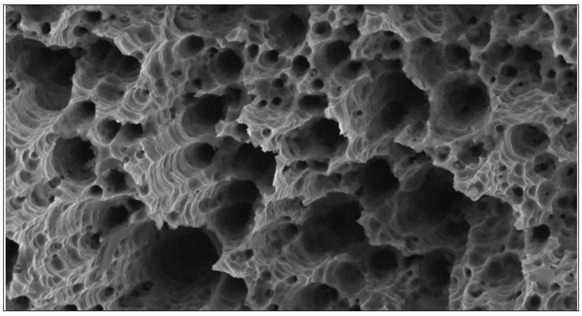
Approach: Four types of aluminum alloys of various compositions, shapes and structures were evaluated through several test methods. Aluminum particles in the magnitude of millimeters are studied as this size will be used by the combined heat and power reactor. The reaction rate is determined by measuring pressure increase during the reaction. Water, the hydroxy promoter and aluminum are mixed in a sealed system with a pressure measurement device on top. The rates of hydrogen production are analyzed as the parameters are adjusted. Reaction products are analyzed through X-Ray diffraction. The reaction models are defined by data analysis and confirmed through microscopic observation.

Result: The reaction was performed with sodium hydroxide at various molarities. 3M solution was determined to be the mildest recommended conditions. The reaction was analyzed between 50°C-80°C, with the increase in reaction rate slowing down after 70°C. Addition of a salt promoters does not offer any benefit to the reaction kinetics. Three of the aluminum samples show a high correlation to the shrinking core model. In this model, the reaction between aluminum and water occurs exclusively at the particle surface which decreases in size over time. One aluminum sample, cut wire, correlates to the random pore model, where the reaction takes place on both the surface and inner pores of the particle. The reaction models were confirmed by microscopic analysis of the test materials.

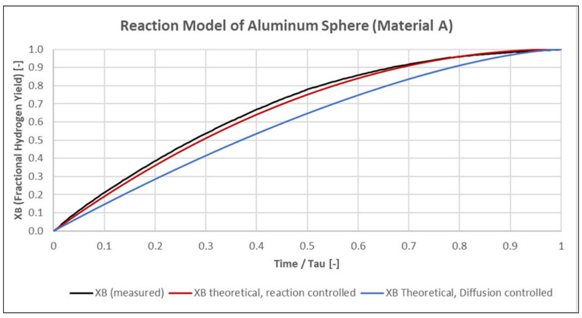
Sketch of the test set-up to measure hydrogen production.
Own presentment



Microscopic analysis of aluminum cut wire test samples after partial reaction with water.
Own presentment



Example of the shrinking core model compared to test results obtained on aluminum spheres.
Own presentment



Advisor
Prof. Dr. Andre Heel

Subject Area
Energy and Environment