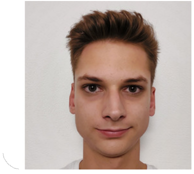
Alu-to-Energy Conversion

Small Scale Lab Reactor System

Graduate



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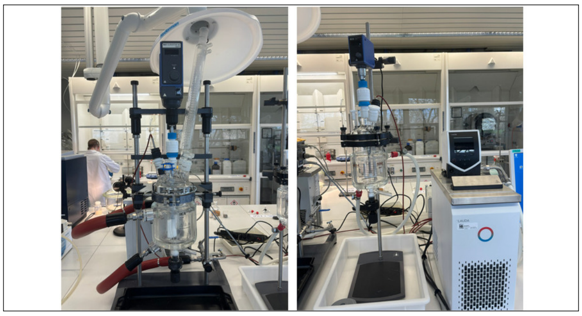
Introduction: Renewable energies are a more environmentally friendly alternative to fossil fuels. However, in winter, renewable energy production in Switzerland is not sufficient to meet demand, so fossil fuels continue to be used, which increase greenhouse gases in the atmosphere.
To solve this problem, the chemical reaction between CO2-free aluminium and water can be used to produce hydrogen, aluminium hydroxide and heat. The hydrogen produced can be converted into electricity using a fuel cell, while the heat can be used to heat buildings. The aluminium hydroxide can be converted back into aluminium, closing the cycle. This process can ensure a steady flow of renewable energy even in winter months. Since aluminium achieves a higher energy density per volume than hydrogen and no compression, compressed gas cylinders or cryogenic storage is required for storage, the use of aluminium has significant advantages over hydrogen.

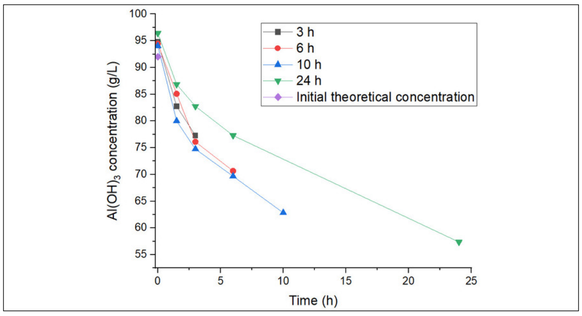
Definition of Task: The main objective of the project is to investigate the influence of four different cooling rates on the precipitation of aluminium hydroxide formed during the aluminium-water reaction in sodium hydroxide solution (NaOH). The laboratory setup comprises a reactor in which the reaction between aluminium and water takes place and a crystallization reactor in which the solution is cooled and the crystallization of solid aluminium hydroxide is promoted. Four cooling times were selected for cooling from 80 °C to 25 °C: 24 h, 10 h, 6 h and 3 h. Crystallization was promoted by adding seed crystals, the morphology of which was previously determined in an initial experiment. The precipitation of aluminium hydroxide from the reaction solution is of crucial importance, as it enables the recovery of alumiinum by calcination and subsequent electrolysis in a process that uses inert anodes and an electrolyte that is based on molten cryolite. it is important to achieve a high precipitation rate and removal of aluminium hydroxide for economic reasons and also to obtain rather large aluminium-hydroxide particles that are suitable for the subsequent calcination.

Result: The results show that the experiment with the 10-hour cooling period achieves the highest precipitation rate, while the 24-hour experiment precipitates a higher percentage, but at a lower rate. Therefore, the 10-hour experiment seems to find the right balance between cooling rate and supersaturation of the solution, while the other experiments either cool too fast or too slow. If cooling is too slow: As precipitation progresses, supersaturation (crystallization forces) decreases and consequently the precipitation rate reduces. If cooling is too fast: The temperature drops and, as the Arrhenius law describes, the chemical processes take place more slowly at lower temperatures, which reduces the rate of precipitation. Unfortunately, the cooling rates tested are not sufficient to achieve the rate of aluminium hydroxide precipitation required for the targeted performance of the aluminium reactor. Therefore, other methods need to be explored in the future, such as the use of variable cooling ramps, or the use of higher concentrations of caustic (NaOH) and aluminium hydroxide.

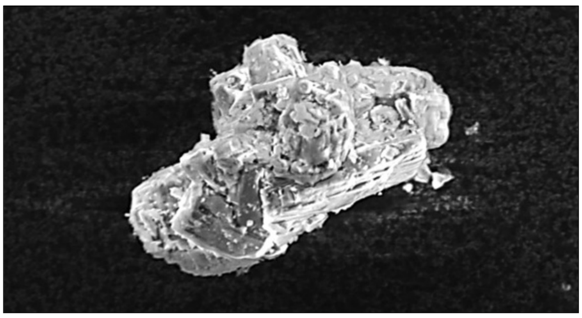
Left: Reactor for the aluminium-water reaction, right: Setup for cooling, cristallization and precipitation of Al(OH)3
Own presentment



Aluminium hydroxide concentration as a function of cooling time, each experiment starting at 80 °C and ending at 25 °C
Own presentment



Analysis of the aluminium hydroxide morphology of the 24-hour experiment
Own presentment



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Subject Area
General energy technology