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Hydrogen production by aluminum corrosion: Experimental investigation and mathematical modeling

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Abstract. The search for new energy sources has been a great focus lately because of concerns about climate change caused mainly by fossil fuels gas emissions. The hydrogen is a promising energy source due its clean and high energy combustion. However, the major drawbacks to use hydrogen are the difficulty of formation, transportation and storage. The objective of this work is the study of hydrogen formation by aluminium reaction with water by using strong alkalis as catalysts (NaOH and KOH), and the development of a mathematical model that accounts the evolution of hydrogen at each time. Different alkali concentrations were used (1, 1.5, 2, 2.5 and 3 mol·L^{-1}). The reactions were carried out with aluminum in different samples: foils, plates with 0.5 mm and 1 mm width each. The range of temperatures studied was: 295, 305, 315 and 325 K for foils and 0.5 mm plates; 315, 325, 335 and 345 K for 1 mm plates. The results showed a strong dependence of the reaction rate on the temperature, alkali concentration and shape of the samples. The model predictions of hydrogen formation agreed with the experimental data of volume *versus* time, as well as the peaks observed in the reaction rates.

Key words

hydrogen, fuel cell, aluminum, alkaline corrosion

1. Introduction

Several investigations about new energy sources have been carried out during the last decades. Concerns about a possible depletion of petroleum, coal and gas, as well as new methods to achieve a more reasonable use of these raw materials to obtain energy have been widely investigated at present, especially some studies about the reduction of green house gases.

The hydrogen has a very high combustion heat (HHV = 141.90 kJ·g^{-1}, LHV = 119.9 kJ·g^{-1}), which is a promising alternative in terms of energy. However, hydrogen must be generated by means of some chemical reaction, because this gas is not encountered available as "H_2" in nature. It is also a very difficult liquefying H_2 to be transported or stored ([1]). Based upon these considerations, the objective of this work is the production of high purity hydrogen via aluminum-water reaction by applying a catalyst to speed up the rate of gas formation. The presence of the catalyst (strong alkali, NaOH and KOH) is necessary because the reaction of the metal with water does not occur due to presence of a very thin passivation layer, Al_2O_3, which hinders the reaction ([6] e [3]). The use of alkalis, like NaOH and KOH, promotes the complete removal of this layer, so that the reaction with water may proceed ([4], [5]). The reaction that occurs is as follow:

$$Al + 3H_2O \rightarrow Al(OH)_3 + \frac{3}{2}H_2$$

Different mechanisms have been proposed for the reaction presented. In [8], the formation of an intermediate (pseudoboehmite, AlOOH) was considered in a mathematical approach that accounts for the pressure of the hydrogen bubbles formed under the metal surface, thickness of the hydrated oxide film, and other effects. Also, $NaAl(OH)_4$ was considered an intermediate compound, and the replacement of NaOH by $NaAlO_2$ as catalyst was successfully verified ([4],[5]).

2. Experimental apparatus

The reactions were performed in an inverted and sealed 60 mL syringe where, both alkali solutions and aluminum samples (range about 34-37 mg of metal) were inserted. The syringes were immersed in a thermostatic water bath up to the level of alkali solution (5 mL), as depicted in Figure 1.

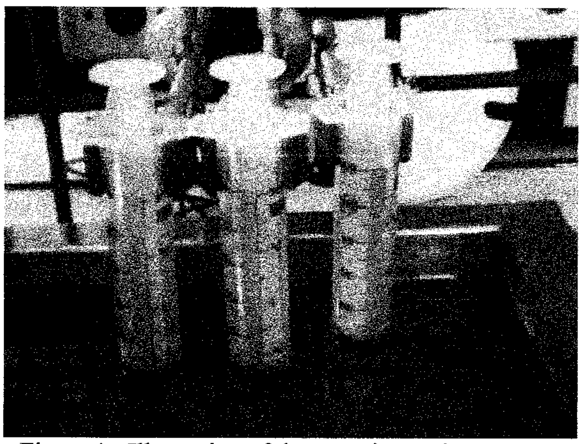

Figure 1 - Illustration of the experimental apparatus.

The needles were inserted in silicone stopper to avoid leaking of solution inside the thermostatic water bath. Hydrogen formation was measured by displacement of the piston during time and registering the corresponding