

Environmental alternative of processing recycled Aluminum metals to produce simultaneously value-added products such as, Green H₂ Gas, Heat and NaAl(OH)₄

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Green H₂ production is essential for moving from the “Oil” to the “Hydrogen” Economy thus reducing the CO₂ emissions drastically in order to combat extreme climatic changes. Hydrogen gas is the cleanest fuel for electricity production by using H₂/Fuel Cells as well as for other applications. The objective of the present study was to find an environmental alternative of processing recycled Aluminum metals such as, Shavings (Chips), Cans (Flatten/Shredded) and Slabs (Chunks) by catalytic (in the presence of NaOH) reaction with water (of any quality, even sea-water), to produce Green H₂ gas, Heat and value-added useful industrial products such as NaAl(OH)₄.

Objectives

NaOH

1. Mechanism of reaction: $\text{Al} + 3\text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + (3/2)\text{H}_2$, the NaOH acts as a catalyst (Prototype#1)
2. Hydrogen production rate for different type of recycled Aluminum metals (Shavings, Cans and Slabs) under different NaOH wt% Concentrations (Prototype#2)
3. Hydrogen production rate for recycled Aluminum metals in the form of Flatten and Shredded Al Cans under 10wt% NaOH (Prototype#3)

Experimental

During the study, three Experimental Prototypes with a capacity of 0.4-1g (Figure 1(a)), 10-50g (Figure 1(b)) and 0.25-1kg (Figure 1(c)) were designed and constructed as shown in Figure 1.

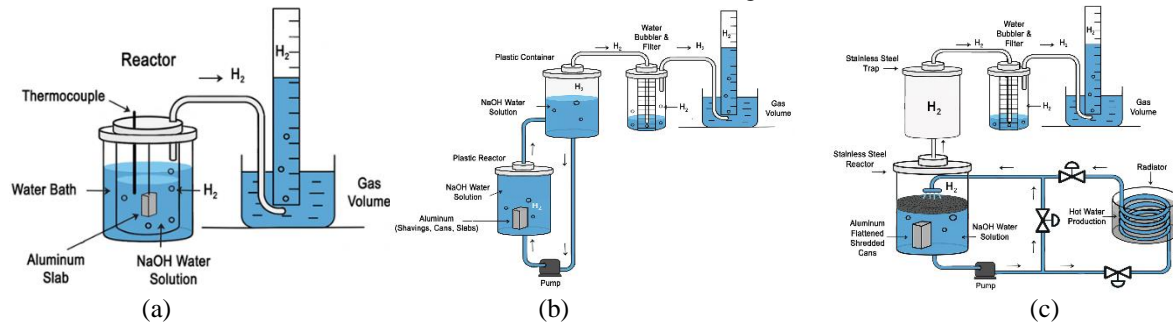


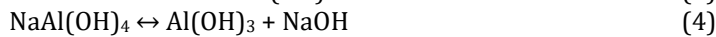
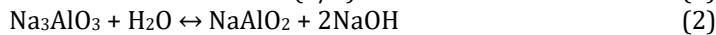
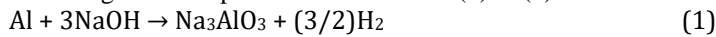
Figure 1. Experimental Prototype#1 (under no agitation/stagnant conditions), Prototype#2 (under continues pump circulation/agitation) and Prototype#3 (under continues pump circulation/agitation)

Experimental Results and Discussion

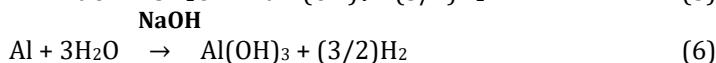
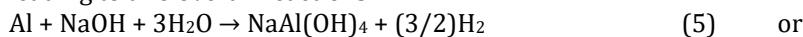
NaOH

➤ **Mechanism of reaction:** $\text{Al} + 3\text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + (3/2)\text{H}_2$, the NaOH acts as a catalyst (Prototype#1)

Al metal always has an Al₂O₃ on its surface which protects Al metal from further oxidation. In the presence of NaOH water solution, the Al₂O₃ dissolves ($\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$) into water-soluble NaAl(OH)₄ thus exposing a new clean Al surface which can react according to the exothermic amphoteric reaction (1), producing H₂ gas and different intermediate products such as, Na₃AlO₃ (Sodium Aluminate), NaAlO₂ (Sodium meta-Aluminate), NaAl(OH)₄ (Hydrated Sodium meta-Aluminate) and Al(OH)₃ (Aluminum Hydroxide) according to the amphidromous reactions (2) to (4):



leading to two overall reactions:



➤ **Hydrogen production rate for different type of recycled Aluminum metals (Shavings, Cans and Slabs) under different NaOH wt% Concentrations (Prototype#2)**

It is clear that under similar conditions the H₂ production rate is higher for Shavings than for Cans than for Slabs due to their corresponding higher specific surface areas.

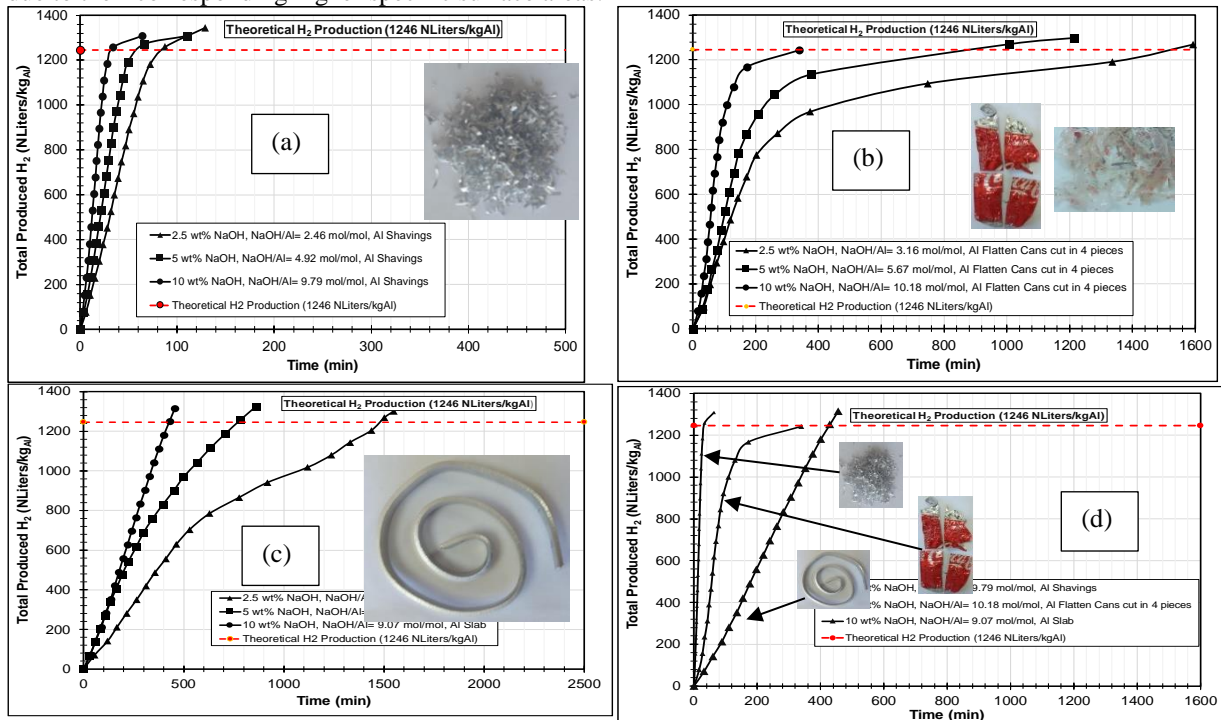


Figure 2: H₂ production rate of recycled Aluminum Shavings (a), Cans (b) and Slabs (c) for different NaOH wt% concentrations and molecular NaOH/Al ratios (mol/mol) of >1/1. Comparison (d) of H₂ production rate of recycled Aluminum Shavings, Cans and Slabs for 10wt% NaOH and similar molecular NaOH/Al ratios

➤ **Hydrogen production rate for recycled Aluminum metals in the form of Flatten and Shredded Al Cans (Prototype#3)**

It is apparent from Figure 3 that, due to their higher specific surface, shredded Al Cans react faster than the Flatten Al Cans, both producing heat for hot water production

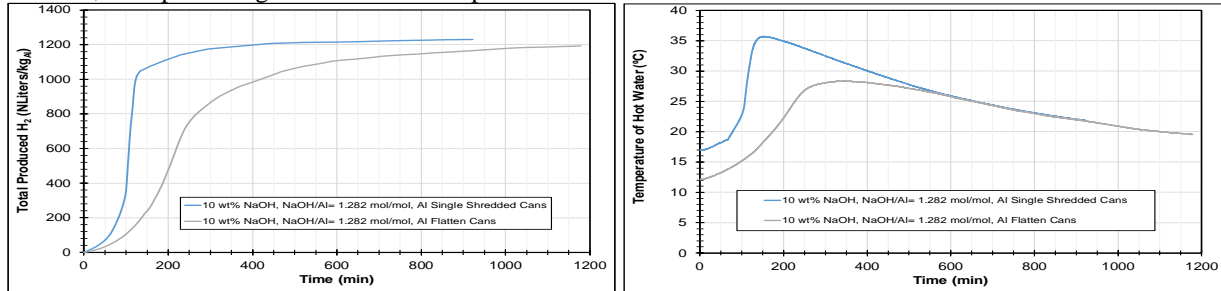


Figure 3: Comparison of H₂ production rate and heated water temperature of recycled Flatten and Shredded Aluminum Cans under 10wt% NaOH water solution and a molecular NaOH/Al ratio (mol/mol) of 1.282.

Conclusions

Three experimental prototypes were designed, constructed and operated smoothly obtaining results on the production of green H₂ gas by using recycled Aluminum Shavings, Cans and Slabs, which is higher due to their corresponding higher specific surface area. The H₂ production was found to be very close to the theoretical 1246NLH₂ per kgAl (3H/Al atom/atom ratio), within ±10% depending on the purity of the recycled Aluminum and taking into consideration the experimental error involved. It was found that As the NaOH wt% concentration increases the reaction rate increases. For high NaOH wt% concentrations, the produced NaAl(OH)₄ remains in solution whereas for low NaOH wt% concentrations, it further decomposes into Al(OH)₃ precipitates (white precipitate) and regenerated NaOH catalyst. The ultimate target of the project is to design and construct a 50kg recycled Aluminium per day large Prototype Unit similar to Prototype#3 of Figure 3. The project (COM-CONCEPT ENERGY/0624/0004/HY-CIRCULAR, “Greening Circular Economy by Innovative transformation of Reuse Recycled Aluminium into Green Hydrogen”, Hystore Tech Ltd, April 1, 2025 to March 31, 2026) was funded by RIF, under the «Commercial Proof of Concept - Energy» Programme and through the Recovery and Resilience Facility of the NextGenerationEU instrument.