EXPERIMENTAL STUDY OF EFFECT OF ANOLYTE CONCENTRATION AND ELECTRICAL POTENTIAL ON ELECTROLYZER PERFORMANCE IN THERMOCHEMICAL HYDROGEN PRODUCTION USING THE CU-CL CYCLE

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Introduction

- With regards to increasing demand for energy, there is a push towards clean energy sources and carriers such as hydrogen.
- The copper-chlorine (Cu-Cl) thermochemical cycle exhibits promise because it requires heat at relatively moderate peak temperatures (approx. 500 °C).
- An important step in the Cu-Cl water splitting cycle for hydrogen production is electrolysis, which occurs after a series of cycle steps that produce the constituents for the anolyte of the electrochemical cell.

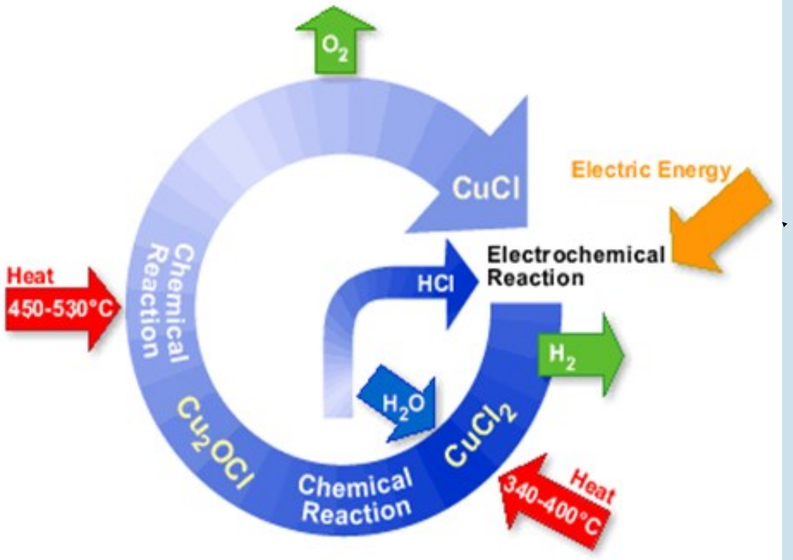

Figure 1: Engineering scaled schematic of copper-chlorine cycle

Overall hydrogen production reactions :

Electrolysis: $2CuCl_{(aq)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + 2CuCl_{2\,(aq)}$,363K,1bar

Drying: $2CuCl_{2\,(aq)} \rightarrow 2CuCl_{2\,(s)} + H_2O_{(g)}$,400K

Hydrolysis: $H_2O_{(g)} + 2CuCl_{2\,(s)} \rightarrow Cu_2OCl_{2\,(s)} + 2HCl_{(g)}$,700K

Copper oxychloride decomposition: $Cu_2OCl_{2\,(s)} \rightarrow O_{2\,(g)} + 2CuCl_{(l)}$,800K

Research Objective

- Experimental investigation to find optimum $HCl_{(aq)}$ conc. of an anolyte mixture of HCl/$CuCl/H_2O$ where the performance of Proton Exchange Membrane (PEM) electrolyzer is maximal.

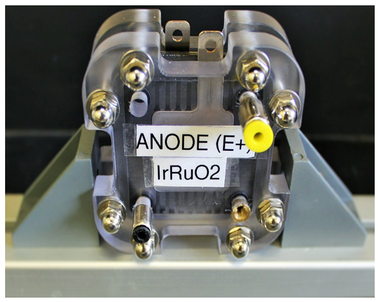

Figure 2: PEM Electrolyzer

Approach and Methodology

A 4.8 cm^2 PEM electrolyzer was connected in series with the electrochemical cell.

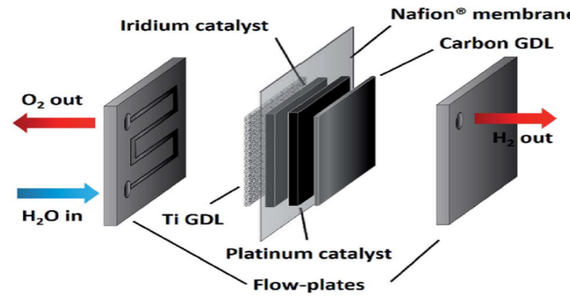

Figure 3: Electrolyzer setup with 3-layer membrane electrode assembly (MEA) and a Proton exchange membrane (PEM) -Nafion 115

Four anolyte solutions were prepared based on the solubility curve in Figure 3:

(a) 4.130 g of CuCl in 0.2 L 1M HCl

(b) 8.030 g of CuCl in 0.2 L 3M HCl

(c) 23.03 g of CuCl in 0.2 L 6M HCl

(d) 39.16 g of CuCl in 0.2 L 9M HCl

Figure 4: Solubility of CuCl powder in $HCl_{(aq)}$ solution at 25 °C

The hydrogen production reaction was accomplished:

- The Omega DC power supply: 0.6 - 0.9 V
- LongerPump peristatic pump flow rate:15 - 25 ml/min

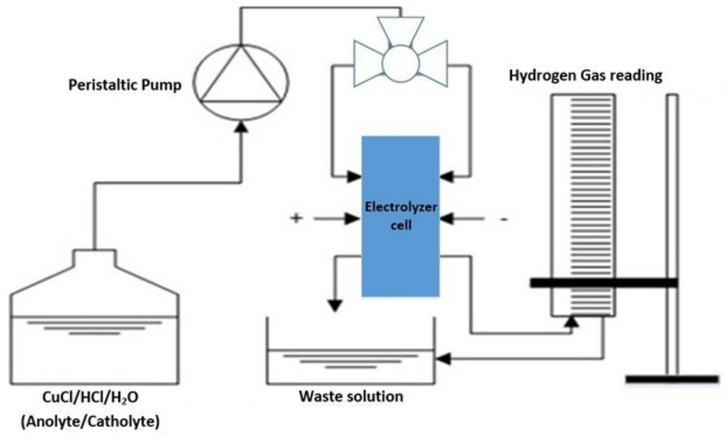

Figure 5: Schematic diagram of the electrochemical cell

Results

- The CuCl/HCl electrolysis was conducted for 15 minutes at 25 °C, standard atmospheric pressure (1 atm) and an electric potential range of 0.6 V to 0.9 V.
- Following reactions took place in PEM electrolyzer:

Oxidation : $Cu^{+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + e^{-}$

Reduction : $H^{+}_{(aq)} + e^{-} \rightarrow 0.5\ H_{2\,(g)}$

Precipitation: $Cu^{2+}_{(aq)} + 2Cl^{-} \rightarrow CuCl_{(aq)}$

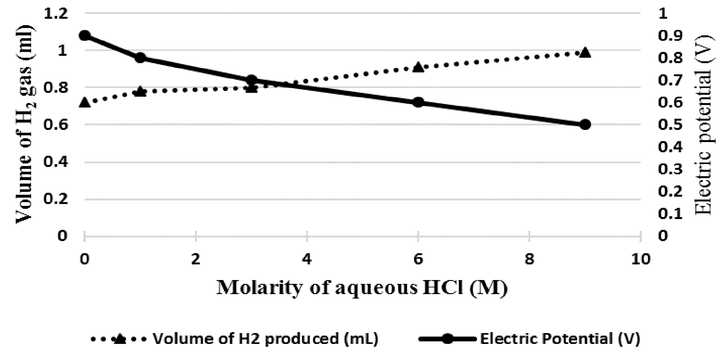

Figure 6: Relation between volume of $H_{2\,(g)}$ with potential voltage drop and changing molarity of HCl

- Results shows that using a 3.7 M HCl concentration instead of a higher concentration of HCl helps to maximize volume of $H_{2\,(g)}$ produced at the cost of lower electrical energy consumed.
- Also the copper crossover would be minimal.

Conclusion

- 3.7 M $HCl_{(aq)}$ is recommended for anolyte mixture.
- Using 3.7M $HCl_{(aq)}$ conc. will avoid the corrosion of electrodes and provides cost-effectiveness solution for membrane.

Future work

- Future enhancements in this work include using different membranes and electrode configurations to avoid copper migration.
- Minimizing the operational cost with an integrated setup for Cu-Cl cycle merits further research.

Acknowledgements

Ontario Research Fund

NSERC CRSNG

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens