

## ChE-455/555: Analysis of Electrochemical Systems

### Experiment 1: Electrolysis of Water

#### 1. Introduction

Electrolysis means passing an electric current through an ionized medium to cause a chemical reaction. The container in which electrolysis is carried out is called an electrolytic cell. An electrode is a conductor in a circuit that carries electrons to or from a substance. The positive electrode, at which electrons are produced, is called the anode. The electrode at which electrons are consumed is the cathode and is labeled as the negative electrode.

Electrolysis only occurs when enough electrically charged ions are present in an electrolytic medium to carry an electric current. Distilled water does not conduct electric current, because distilled water contains no current ions. However, the presence of a small amount of an electrolyte such as sulfuric acid allows water to conduct electricity. Under these conditions, water ( $\text{H}_2\text{O}$ ) can be separated into hydrogen and oxygen. Electrons flow from the anode to the cathode. When a current is passed through the dilute sulfuric acid electrolyte, positively charged hydrogen ions ( $\text{H}^+$ ) are drawn to the cathode side of the electrical source. At the cathode they gain an electron and become hydrogen atoms (H). Pairs of hydrogen atoms then combine to form hydrogen gas ( $\text{H}_2$ ), which bubbles up from the cathode. Similarly, oxygen ( $\text{O}_2$ ) is produced at the anode side by a process involving the loss of electrons.

#### 2. Purpose

The purpose of this experiment is to demonstrate different aspects involved during an electrolysis process. The specific objectives include:

1. Determine the total power consumed during an electrolysis of water
2. Identify the reactions involved during a water electrolysis
3. Calculate current efficiency
4. Verify the stoichiometry of the reaction
5. Evaluate kinetics and thermodynamics feasibility of an electrolysis process
6. Determine the effect of electrode materials on the process efficiency

#### 3. Materials

Hoffman apparatus;

Two platinum electrodes;

Two graphite electrodes;

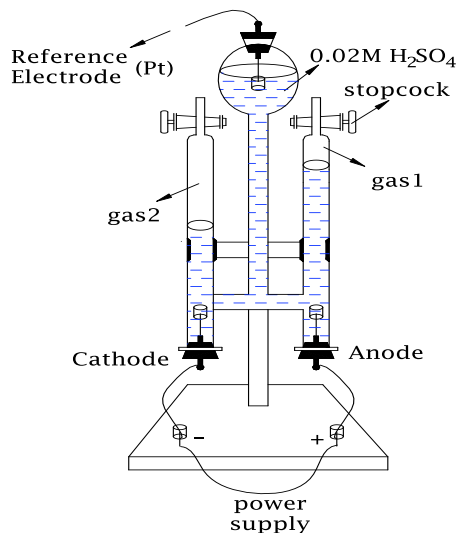
Approximately 300 ml distilled water mixed with 0.3 ml of sulfuric acid (high concentration);

DC Power supply; Voltage meter;

Potentiostat;

distilled water, 600 ml beaker, stirring rod;

## Hoffman Electrolysis Apparatus



### 4. Procedure

1. Prepare a 0.02 M sulfuric acid solution. Pipette 0.3 ml high density ( $18.4\text{g/cm}^3$ )  $\text{H}_2\text{SO}_4$  into a 600 ml beaker and make the solution to 300 ml.
2. Insert the electrodes (Pt) on the Hoffman apparatus and mount the apparatus on the column stand. Open the stopcocks on the Hoffman apparatus, and fill the apparatus with dilute sulfuric acid solution. And then insert the reference electrode on the top of bulb.
3. Measure the potential difference with voltage meter between the two arms of dilute sulfuric solution. Change the two electrical probes of voltage meter until a positive potential difference is obtained. Connect the red and white wires to the positive terminal, and the black and green wires to the negative terminal.
4. Set a stable DC Power to the electrolysis through the Potentiostat (Determine the potential at which you will observe reactions). Adjust the power supply to the value that your group will be assigned and the time for electrolysis running to 1 hour. Bubbles should be evolved quickly on both electrodes. The gases will rise up to the top of the arms where it can be collected and identified using a gas syringe to the Gas Chromatography.
5. Allow the electrolysis to continue during the experiment.
6. Towards the end of the class (about 1 hour) you should measure the volumes of gases through the graduated tubes of the Hoffman apparatus and disconnect the wires.
7. Collect the gaseous products using a syringe to the gas chromatography and identify the gases.
8. Disconnect the Potentiostat wires. Make sure the power supply is off and turned down to the lowest settings. Close the stopcocks and pour the sulfuric acid solution back into the beaker from the bulb until the middle arm of the apparatus is emptied. Empty the other arm through the stopcocks.

9. Repeat the process using the graphite electrodes. It is recommended to run the two experiments simultaneously (the electrolysis using Pt electrodes and the electrolysis using graphite electrodes)
10. Rinse the apparatus with plenty of water and then distilled water. Remove the electrodes and rinse with distilled water. Let the apparatus and electrodes dry.
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## 5. Hazards

Although power sources used are relatively weak, electrodes should not be handled while cells are operating. Prepare and handle the sulfuric acid with care because it is aggressive and causes skin irritation. Goggles and gloves must be worn throughout the experiments.

## 6. Discussion

1. What is the trace of electrons flow in this system during the electrolysis?
2. What is the minimum potential that you need to apply to produce gases?
3. What's the purpose of sulfuric acid?
4. What are the gases produced during the electrolysis (use GC to identify the components) when using Pt and graphite electrodes? Why is the difference in the ratio of the gases when using the different electrode materials?
5. Calculate and discuss the stoichiometry of the reactions. Postulate reactions.
6. Calculate the current efficiency. Discuss (is there any parasitic process? Which one?)
7. Write down the net equation for the reaction in this system.
8. What is the total power consumed during the processes?
9. If power supply is increased, what would happen with your reactions?
10. What other species can be oxidized or reduced in this system?
11. Is the electrolysis of water kinetically and thermodynamically feasible when using Pt electrodes? What about when using Graphite electrodes? Which electrode material is kinetically more favorable for water electrolysis in acidic media?

**NOTE:** Make sure to report uncertainties in your data and calculations.