

CHAPTER 1 INTRODUCTION

The science of electrochemistry is concerned with electron transfer at the solution/electrode interface. Most of the basic principles and relationships, however, were described prior to the discovery of the electron by J. J. Thompson in 1893. In 1800, Alessandro Volta invented the first battery, then known as a voltaic pile, by alternating stacks of copper and zinc disks separated by paper soaked in acid solutions. With the discovery of a sustainable source of electrical current, the stage was set for the rapid development of the area of science now known as electrochemistry. The first quantitative studies of electrolysis are carried out by Faraday in 1833. The wires or electrodes which are immersed in the solution are called the anode and the cathode, respectively. The anode may be defined as the electrode at which negative electricity leaves the solution and the cathode as the electrode at which negative electricity enters the solution. These definitions are universal and apply to any situation. The solution which carries the current is termed the electrolyte that in the immediate neighborhood of the anode being the anolyte and that around the cathode being the catholyte. To account for the passage of a current through the electrolyte, Faraday assumed that the flow of electricity is due to the movement of charged particles which called ions (Denaro, 1971).

1.1 State of Problem

Hydrogen is the most abundant element on the Earth that is common in the environment mostly in the form of compounds such as water or hydrocarbon. Hydrogen can be used as energy carrier for various human activities, for example, a fuel for combustion to produce electricity (Das, et al., 2000; Kruger, 2000; Kruger, 2001) or fuel cells to provide a broad range of energy services and a starting material in the production of precursor chemicals (Ni, et al.,2006). Having the highest energy content on a mass basis, hydrogen can be used as a storage medium. Hydrogen production from a common compound in nature can be done several ways (Zeng and Zhang, 2010) such as electrolysis process and reforming etc. The widespread use of hydrogen could address issues concerning energy security and air quality. When combined with fuel cell technology, combustion technology and energy storage, hydrogen offers the following benefits:

- Strengthen national energy security: by utilizing hydrogen in addition to other alternative energy sources.
- Improve energy efficiency: Fuel cells are significantly more energy efficient than combustion-based power generation technologies. A conventional combustion-based power plant typically generates electricity. Excess electric power can be stored by the transformation of energy.
- Reduce air pollution: The combustion of fossil fuels from vehicles and power plant is responsible for most of the smog and particulates.

The Technology to produce hydrogen gas can be divided into three-core technologies including thermal process, electrolysis process and photolytic process (Casper, 1978; Conibeer and Richards, 2007; Miri and Mraoui, 2007; Soltermann and Da Silva, 1998; Zeng and Zhang, 2010). The most popular method used to produce commercial hydrogen is thermal process through steam reforming using gas or oil as a raw material (Marcelo and Dell'Era, 2008); however, the raw materials from fossil fuels are being diminished. In addition, the problem with producing hydrogen from fossil fuel is that greenhouse gases are produced in the process which can cause a severe environmental impact.

The growing demand for fossil fuels and petroleum in particular, will result in higher energy costs and greater reliance on imported oil. This can have a potentially negative impact on the nation's economic growth as rising commodity prices are closely tied to inflation rates. It is necessary to find new energy sources to maintain energy stability. Electrolysis process is gaining importance among the conventional processes of hydrogen production. Its principle lies on the fact that water can be separated into hydrogen and oxygen when electricity is charged into the electrodes submerged into an electrolyte. It has the advantage of producing extremely pure hydrogen and oxygen and reducing reliance on fossil fuels (Davies, 1959; Zeng and Zhang, 2010). This makes water an attractive feedstock since it can be recycled back into nature indefinitely. When hydrogen is burned in an internal combustion engine or oxidized in a fuel cell, it bonds with oxygen in the air, forms steam and drifts off into the atmosphere to become clouds. The clouds rain down as water which can be used again to create hydrogen and the cycle continues. One of the disadvantages of creating hydrogen from water is that high energy extent is used in the process and it is still in doubt if the process is totally

clean from the beginning to the end. As a result, the electrolysis process is not widely accepted due to the high cost of energy consumption (Marcelo and Dell'Era, 2008; Tani, et al., 2000) and efficiency of process (Nagai, et al., 2003; Schug, 1998; Weber and Stahl, 2002).

Alkaline water electrolysis has been developed in this work due to its low capital cost and uncomplicated technology in which water splitting in its simplest form uses an electrical current passing through two electrodes to break water into hydrogen and oxygen. Factors associated with gases such as electrode materials, types of electrolyte solution, operating temperature, distance between electrodes, current density, flow of solution, types of power source and arrangement of electrodes which affect the amount of hydrogen production are requirements. Therefore, this thesis studies the effect of the alkaline electrolysis reaction in the form of electrolyte conductivity via both numerical and empirical models and compares them with the experimental results. In addition, the factors affecting the incidence of hydrogen production and rate of energy consumption at various conditions are studied and served as guidelines for improvement of equipment to increase efficiency of energy use in the hydrogen production by the electrolysis process along with the ways to improve the applications of electrolysis process for the promotion of hydrogen as a fuel for the future. The results will be subsequently discussed.

1.2 Aims and Objectives

The aim of this dissertation is to improve the hydrogen production rate and energy efficiency of the electrolysis process. The effects of the amount of current, temperature, current characteristics, materials, electrolyte solution, concentration and surface area on the hydrogen production rate and efficiency are studied. A mathematical model of the conservation equation of mass, momentum and energy are also developed and compared with the results.

1.3 Scope of the Research

The scope of the work discussed in this dissertation pertains to study parameters affecting energy consumption in hydrogen production from alkaline water electrolysis process and to create the mathematical model of the conservation of mass, momentum

and energy. It begins with a study of fundamental factors of electrochemistry. These factors are presented and tested if they affect the hydrogen production and the relative amount of energy to produce hydrogen. In addition, the mathematical models for the hydrogen production through electrolysis processes will be developed in this study and improved to increase energy efficiency in the hydrogen production.

1.4 Thesis Outline

The thesis is divided into five different chapters. To set the story for a detailed description of the study and its outcomes, this chapter (Chapter 1) outlines the state of problem and context of the study together with its purpose, scope and significance. In Chapter 2, aspects of electrochemical theory relevant to the thesis are described and the concepts of mathematical modeling and experimental are introduced. Further, the literature review is accessed and incorporated at various stages in the research. Chapter 3 demonstrates the theory and the modeling used for characterization of conductivity, void fraction and ionic resistance. The main focus is on the development and validation of mathematical model, which are used for the majority of the experimental work. The experimental of those are presented and discussions in Chapter 4 in which a detailed description of the relationship between variables and the factors affecting the hydrogen production rate and the efficiency are contained. Finally, in Chapter 5, the thesis is summarized and its potential to be further extended through future research is suggested.