CHAPTER I
INTRODUCTION

Chlorine is a highly reactive chemical that ranks among the ten most important commodity chemicals. As of January 1999, a total annual capacity of almost 50 million tons of chlorine was reported (Berthiaume *et al.* 2000). The applications of this chemical are so varied that hardly a consumer product is produced that is not dependent, at some stage in its manufacture. The industries for the production of plastics, polymers, solvents, agrochemicals, pharmaceuticals, and household bleach are entirely reliant on chlorine.

1.1 The Production of Chlorine

A process, in which an electric current is passed through brine solution, is used to produce all present day chlorine. The process consists of brine purification, brine electrolysis, chlorine cooling, chlorine drying, and chlorine compression and liquefaction, as shown in Fig. 1.1. This process is called the Chlor-Alkali process.

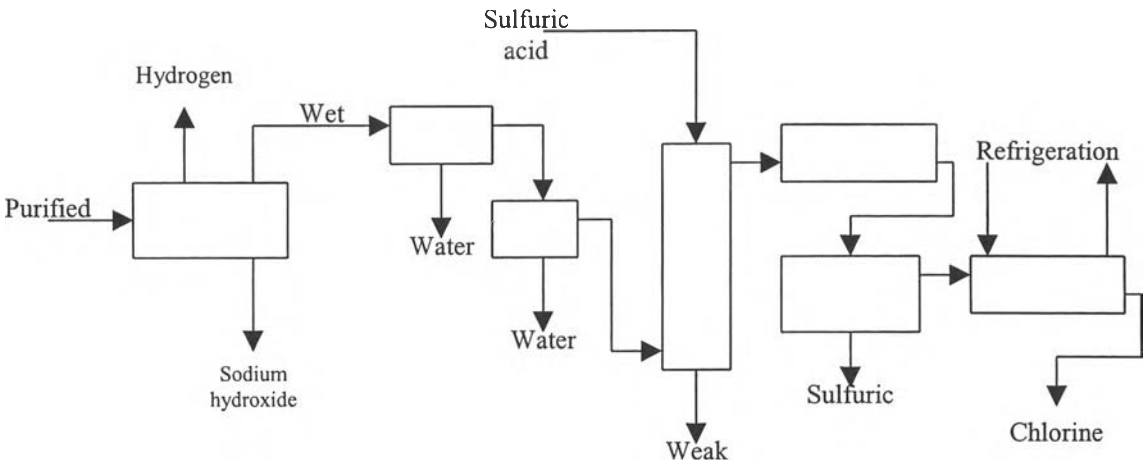

Figure 1.1 Chlorine production flow diagram.

The chemical reaction of the process is written below:

$$2NaCl + 2H_2O \longrightarrow Cl_2 + 2NaOH + H_2$$

In the electrolytic cell, sodium chloride salt in the brine solution is electrolytically split using direct current (DC) electricity, resulting in wet chlorine gas at the anode and available sodium ion (Na+) that is reacted with water in the cell to generate, as co-products, caustic soda and hydrogen gas at the cathode. There are three different types of electrolytic cells used to maintain the separation of chlorine and caustic soda once it has been produced: mercury cells, diaphragm cells, and membrane cell as shown in Fig 1.2 (Raymond, 1998).

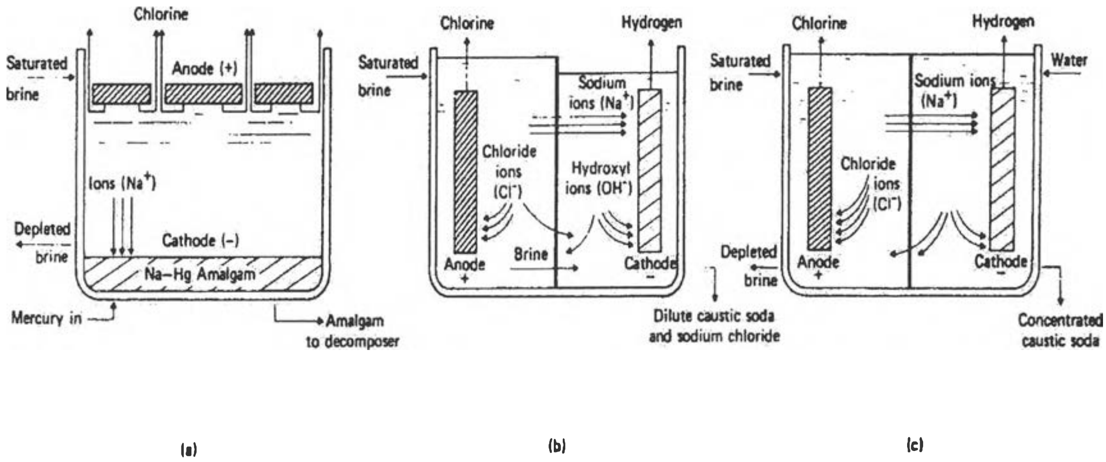

Figure 1.2 Chlorine electrolysis cells: (a) mercury cell; (b) diaphragm cell; (c) membrane cell (Raymond, 1998).

1.2 The Importance of Hydrogen Monitoring in Chlorine Production

Hydrogen is an added complication to chlorine production. To maintain plant efficiency and safety, the amount of hydrogen present in the chlorine stream should be monitored regularly. An increase in the amount of hydrogen generated at the cathode of the electrolytic cell implies that more energy is consumed to produce the desired chemicals. For the plant safety aspect, it is commonly known in the design and operation of chlorine plants that when hydrogen is present in a gas stream with chlorine or with oxygen at hydrogen concentration less than about 4%, dependent upon pressure and temperature, usually the stream is non-explosive. Thus, the amount of hydrogen in the chlorine gas stream is normally controlled to be less than 4%, to avoid hydrogen explosion (Tuft, 1992 and Rakatoarevelo, 1995).

The device used presently; a catharometer, requires the gas to be sampled and analyzed at a laboratory. It can not give continuous monitoring and takes considerable time. So a device that can give an on-site indication of hydrogen concentration in the chlorine gas stream would be more convenient and useful.

1.3 Sensors for Hydrogen Gas Concentration Measurement in the Presence of Chlorine

A sensor can be defined as a device that produces a measurable response by a change in the concentration of a given species. Sensors used universally as a measuring device for hydrogen gas are

1. Pd/H Electrical Resistance sensor
2. Electrochemical Potentiometric sensor
3. Electrochemical Amperometric sensor.

However, these sensors can not be used directly for hydrogen gas concentration measurement in the presence of chlorine. Chlorine nullifies the principle of the sensors leading to an error in hydrogen concentration measurement Therefore, a membrane or a coating material that blocks chlorine while giving good passage of hydrogen is needed. By using a suitable membrane with the sensors, the continuous monitoring of hydrogen concentration in the presence of chlorine could be made practical. This design is referred to as the membrane sensor.

From studies at the Centre for Nuclear Energy Research (1999), Kitjaroenvong (2000) and Kham Sa-Ang (2001), a material that possesses the ability to separate Cl_2 from H_2 is Epoxy vinyl ester resin. No previous study found that the Epoxy vinyl ester resin will allow chlorine to pass through. Especially in Kham Sa-Ang's work, there is no chlorine detected on the other side of the membrane for 160 hours when epoxy vinyl ester resin of the thickness of 0.56 mm. was applied.

Another important feature of the sensor is the time it takes to respond to the change in hydrogen concentration in the stream. According to Fick's Law of diffusion and the study at the Centre for Nuclear Energy Research in October 2000, we know that the response time of the sensor can be improved by reducing the thickness of the membrane.

In this study, we are focusing on a membrane that consists of three layers. The Epoxy vinyl ester resin is used as an active layer between two sheets of Teflon®. This membrane will be referred to as the sandwich membrane in this report. With this sandwich technique, the active layer is expected to be less than 0.10 mm, which is about six times thinner than the previous study of Khamsa-Ang.

No research has been carried out for the ability to withstand chlorine of the thin-active-layer membrane. Moreover, the study of hydrogen-chlorine mixed-gas permeation has never been conducted to see the effect of the presence of chlorine on the permeation of hydrogen through the membrane. Hence, the objectives of this project are to develop sandwich membranes with an even, thin active layer of Epoxy vinyl ester resin, and to study the chlorine resistance of the membrane. It is also expected that this study will help to understand the transport mechanism governing the membrane in the presence of pure hydrogen and pure chlorine as well as the mixture of those two gases.

1.4 Objectives

1. To develop sandwich membranes which have an active layer less than 0.10 mm thick.
2. To study the stability of the sandwich membrane in pure chlorine atmosphere.
3. To study the permeation of hydrogen in chlorine and hydrogen mixed gas.