PERMEABILITY AND SELECTIVITY STUDY OF POLYETHERSULFONE MEMBRANEFOR GAS SEPARATION

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I declare that this thesis entitled "Permeability and Selectivity of Polyethersulfone Membrane for Gas Separation" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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Date : 30 APRIL 2009

Dedicated to my beloved father, mother, and sisters

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ABSTRACT

An asymmetric polyethersulfone (PES) membrane were prepared through a dry/wet phase inversion process. The casting solution developed in this research consisted of PES, 1-methyl-2-pyrolidone (NMP) and methanol. The turbidity test was carried out to find an ideal weight percentage of casting solution. Membrane composition of 22.28 wt% and 26.58 wt% of PES was used for permeability test. PES membrane was divided into three categories; uncoated, coated with polydimethylsiloxane (PDMS) and coated with bromine solution. Permeation test was carried out by testing CO_2, CH_4, N_2 and O_2 permeating through the membrane to check the permeability and selectivity of the respective gas to CH_4. Different coating agent gave different rate of permeate while higher polymer concentration increased the permeation rate. The PES membrane coated with PDMS showed higher selectivity compared to uncoated membrane and membrane coated with bromine solution. The selectivity of CO_2/CH_4 was approximately 2.77, at 26.58wt% of PES concentration coated with 3wt% of PDMS. It was believed that different coating agent strongly affects the membrane performance as well as the polymer concentration.

ABSTRAK

Polyethersulfone (PES) membran yang tidak simetri telah disediakan menggunakan teknik proses yang ringkas iaitu proses fasa balikan basah/kering. Larutan bahan teracuan yang disediakan untuk kajian ini mengandungi PES, 1 metil 2 pyrolidone (NMP) dan metanol. Ujian kekeruhan dijalankan bagi mencari satu peratusan berat yang unggul untuk penyediaan larutan bahan teracuan. Komposisi membran 22.28 wt% dan 26.58 wt% PES digunakan untuk ujian ketelapan. Membran PES dibahagikan kepada tiga kategori; tidak ditutup, disalutkan dengan polidimetilsiloksana (PDMS) dan disalutkan dengan larutan bromin . Ujian penelapan telah dijalankan dengan menguji gas CO_2, CH_4, N_2 dan O_2 ke atas membran untuk melihat ketelapan dan pemilihan bagi setiap gas terhadap gas CH_4. Ejen salutan berbeza memberi nilai ketelapan yang berbeza manakala lebih tinggi kepekatan polimer meningkatkan kadar ketelapan. Membran PES yang bersalut dengan PDMS menunjukkan pemilihan lebih tinggi berbanding dengan membran konvensional dan membran yang bersalut dengan larutan bromin. Oleh itu, pemilihan bagi CO_2 / CH_4 adalah 2.77, pada 26.58wt% bagi kepekatan PES yang disalutkan dengan 3wt% PDMS. Maka ejen salutan dipercayai mempengaruhi prestasi membran dan begitu juga kepekatan polimer.

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CO_2 - Carbon dioxide

PES - Polyethersulfone

O_2 - Oxygen

N_2 - Nitrogen

H_2 - Hydrogen

Cl - Chlorine

H_2S - Hydrogen sulfide

C_2 - Carbon

J - Flowrate of gas through membrane

ℓ - The effective thickness of separation layer

D - Diffusion coefficient in membrane

ΔC - Concentration difference of gas in membrane

S - Solubility coefficient

P - External gas partial pressure

P/ℓ - Gas permeance

P - Permeability coefficient of separation layer

A - Membrane surface area

Δp - Pressure difference of penetrant across membrane

A - Selectivity of gas

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The processed natural gas was a production of purification of raw natural gas. Raw natural gas from underground gas fields extracted and brought up to the surface by gas wells purified by using natural gas processing plant. Raw natural gas consists of methane, heavier gaseous hydrocarbon, acid gases, other gases, water, liquid hydrocarbon and mercury. An example of acid gases was hydrogen sulfide and carbon dioxide. The amount of carbon dioxide should be in small amount because carbon dioxide when react with water, formed a carbonic acid which may corrode the pipeline. In order to meet the quality standards specified by the major pipeline transmission and distribution companies, one of the specifications was to ensure the pipeline was free of particulate solids and liquid water. Therefore, CO_2 should be removed as it should follow the standardization of the standards in gas transmission and distribution codes and practices because CO_2 lead to erosion, corrosion and other damage to the pipeline (Surkov *et al*, 2000).

Currently, amine absorption was commonly used for CO_2 separation process involves amine absorption. In brief, flue gas streams and natural gas streams were bubbled through an amine solution and CO_2 in the streams becomes bound to the amine groups in the solution. Consequently, the CO_2 content in the resulting gas stream was significantly reduced. Amine absorption was an effective technique to remove CO_2;

however, this technique has notable flaws and inefficiencies. Some of the disadvantages of this process was it requires a high amount of energy, tendency to corrode the equipment, loses viability through amine degradation and loss, required high capital cost, complex to install and operated (Lee *et al*., 2000).

New development in gas separation by using membranes provides simple, low cost and compact solutions for reducing CO_2 in natural gas. In this separation process, the membranes acts as a semi permeable barrier and separation occurs by controlling the rate of movement of various molecules between two liquid phases, two gas phases, or a liquid and a gas phase (Geankoplis, 2003).

The selectivity was believed relates to the parameter such as polymer concentration used which strongly affects the membrane performance (Koros *et. al*., 2000). Selectivity of membrane can be represented by the ratio of the permeability of any two components through the membrane. This specific characteristic of a membrane were generally varies inversely with gas permeability which means to achieve a high selectivity, it requires the membrane to operate in low permeability (Scott, 1998).

Based on the previous researchers, the limitations of this research was to achieve high gas permeability without a significant decrease in gas selectivity. Therefore, in order to get the high selectivity membrane without reducing the permeability of membrane, a low cost polymer was sought off. Some of alternatives were using polyethersulfone membrane.

1.2 Problem Statement

There has been a substantial focus on improving techniques for CO_2 sequestration or capture. Today, oil and gas companies were required to remove or substantially reduce CO_2 levels in exhaust streams before they are vented to the atmosphere. Since CO_2 was well known as an acid gas, CO_2 should be removed before natural gas can be distribute to the pipelines.

A simple process technology was highly desirable which can be applied in remote, unattended or offshore situations. In addition to competitive capital and operating costs; ease of operation, quick start-up and high on-stream factors are needed. Currently, amine absorption was commonly used for CO_2 separation process. Amine absorption was an effective technique to remove CO_2; however, this technique complex and have high capital, operating and installation costs; a relatively high fuel cost and potential environmental issues. Therefore new development of separating CO_2 gas using membrane was developed. However the major problems confronting the use of the membrane based gas separation processes in a wide range of applications was the lack of membranes with high selectivity. Therefore, a membrane which has high permeability and also not reducing in the level of selectivity was sought off in order to overcome this problem (Lee *et al*., 2000).

1.3 Objective of Study

The objective of this research was to study the permeability and selectivity of polyethersulfone membrane (PES) for gas separation.

1.4 Scope of Study

In order to meet the objective, there were some scopes which need to be focused:

i) To develop polyethersulfone polymer as a membrane for gas separation
ii) To study the permeability and selectivity of different gases (CO_2,N_2,CH_4 and O_2)
iii) To study the effect of polymer concentration and coating treatment on the membrane performance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Membrane Definition

Membrane can be defined as a layer of material which serves as a selective barrier between two phases and remains impermeable to specific particles or group of particles or substances when exposed to the action of a driving force. Some components allowed passage by the membrane into a permeate stream, whereas others are retained and accumulate in the retentate stream. Membrane with homogeneous or heterogeneous structure can be neutral or charged, and particles transport can be active or passive. The driving force can be facilitated by pressure, concentration, chemical or electrical gradients of the membrane process. Membranes can be generally classified into two groups: artificial membranes or biological membranes. These two types of membranes differ significantly in their structure and functionality (Peter *et al*., 1996).

Membrane in the original word is known as “membrana” in Latin which mean as skin. Another definition of membrane was a selective barrier between two phases (Sakai, 1994). Membrane can also defined as thin barrier that permits selective mass transport or a phase that acts as a barrier to prevent the mass movement, but allows or regulated passage of one or more species (Bhattacharya *et al*., 2004).

2.2 Membrane Module

Large membrane areas are normally required in order to apply membranes on a technical scale. A module was defined as the smallest unit into which the membrane area packed. At certain flow rate and composition, a feed enters the module. Both the feed composition and flow rate inside the module change as a function of distance. This was due to the ability of membrane which able to transport one component more readily than other. There are four major types of modules normally used in membrane separation processes which are plate and frame, spiral wound, tubular and hollow fiber module (Mulder, 1996).

2.2.1 Plate and Frame Module

Plate and frame module can be described as simple and easy maintenance. Two membranes are placed in a sandwich-like fashion with the feed side was faced each other. In each compartment; feed and permeate, the suitable spacer- membrane- support plates are stacked alternately (Wang *et al.*, 2006). Figure 2.1 shows the structure of plate and frame membrane module.

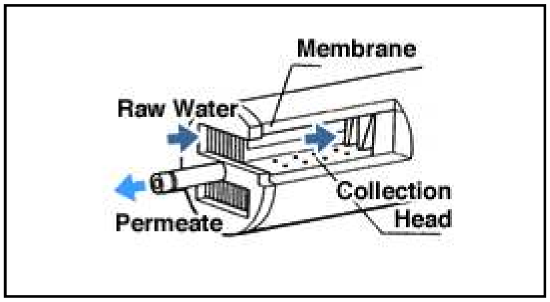


Figure 2.1: The structure of plat and frame membrane module (Yoshihito *et al.*, 1992)

2.2.2 Spiral Wound Module

Figure 2.2 illustrated a structure of spiral wound membrane module. Spiral wound membrane module was formed using a flat sheet membrane. It consist of two layers of membrane, placed into a permeate collector fabric. The membrane envelope was wrapped around a centrally placed permeate drain. This causes the packing density of the membranes to be higher. The feed channel is placed at moderate height, to prevent plugging of the membrane unit. Spiral membranes are only used for nanofiltration and reverse osmosis (RO) applications (Holding, 1998).

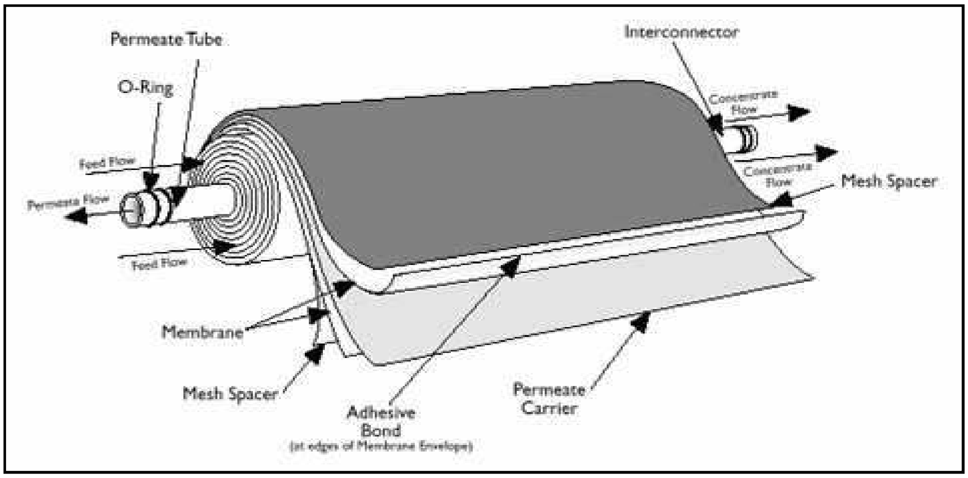


Figure 2.2: Structure of spiral wound membrane module (Yoshihito *et al*., 1992)

2.2.3 Tubular Module

Tubular membranes are not self supporting membrane. It was made of special material and located on the inside of a tube. This module acts as the supporting layer for the membrane. The flow of a tubular membrane was usually inside out due to the location of tubular membranes is inside a tube.

Tubular membranes have a diameter of about 5 to 15 mm and due to this size, plugging of tubular membranes is not likely to occur. A drawback of tubular membranes is that the packing density is low, which results in high pries per module (Baker, 1991). The module was described in Figure 2.3.

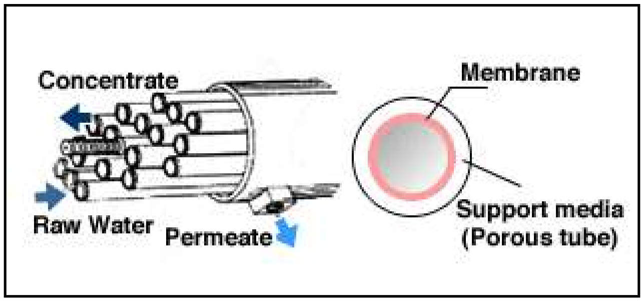


Figure 2.3 : Tubular module diagram (Yoshihito *et al.*, 1992)

2.2.4 Hollow Fiber Module

Hollow fiber membrane has diameter below 0.1 μm which mean the chances of plugging was very high. The membranes can only be use for the treatment of water with low suspended solids content. The packing density of a hollow fiber membrane was very high. Hollow fiber membranes always used merely for nanofiltration and reverse osmosis (RO) (Wang *et al.*, 2006). Structure of hollow fiber module was shown in Figure 2.4.

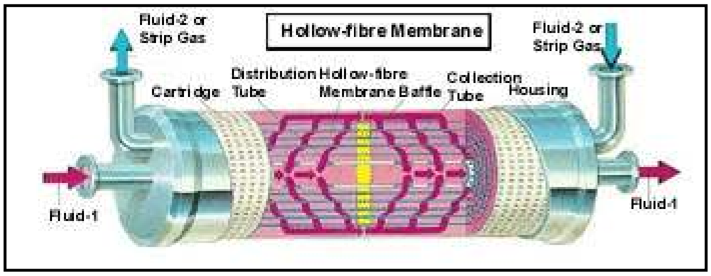


Figure 2.4: Hollow fiber membrane module (Wang *et al.*, 2006)

2.3 Membrane Structure

Typically, there are two types of membrane structure namely, symmetric and asymmetric. The different between these two structures were the physical and chemical properties.

2.3.1 Symmetric Membrane

A symmetric or isotropic membrane was membrane that having the same chemical and physical structure throughout the hole. There are two general type of symmetric membrane; porous and non-porous (Mulder, 1996).

2.3.1.1 Porous Membrane

Porous membrane was when the particle permeate through membrane and particle separation by membrane was considered, the size of the hole, which acts as a passage for the moving particles, becomes one of the indices and a membrane with many holes bored through of about 0.005 – 1 μm in diameter. The selectivity was determined by the dimensions of the pores but the choice of material affects phenomena such as adsorption and chemical stability under condition of actual application and membrane cleaning (Mulder, 1996). Schematic diagram of porous membrane were shown in Figure 2.5.

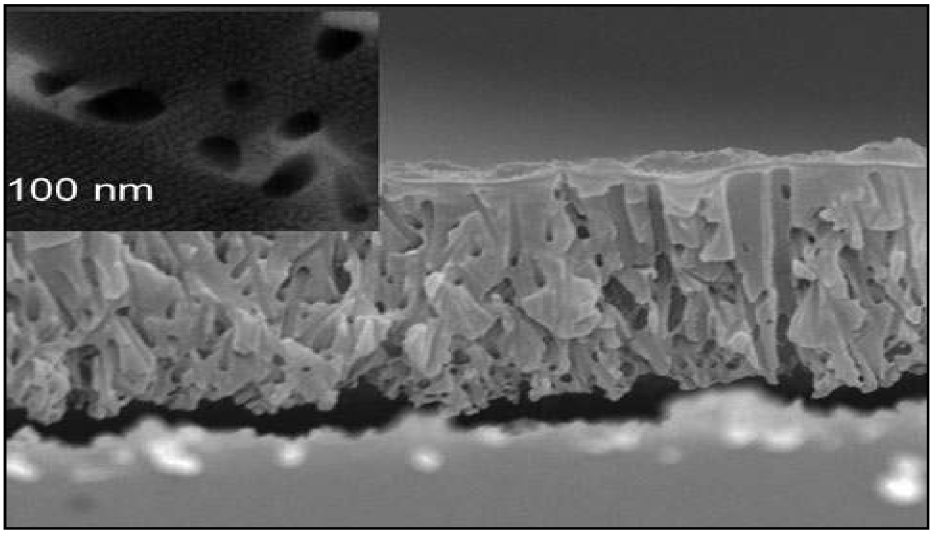


Figure 2.5: Schematic diagram of porous membrane (Berkeley, 2006)

2.3.1.2 Non – porous Membrane

Non –porous membrane has hole smaller than 0.001 µm in diameter. However, it cannot be called a hole; it was a gap between particles based on thermal vibration of the polymer which constitutes the membrane. This membrane usually used in gas and vapour separation and pervaporation. The permeability and selectivity was determined by the intrinsic properties of material. Mass transport through non-porous membrane was best described as "Solution-Diffusion Model", Hartmut Brüschke (Scott, 1998) .Non-porous membrane structure was shown in Figure 2.6.

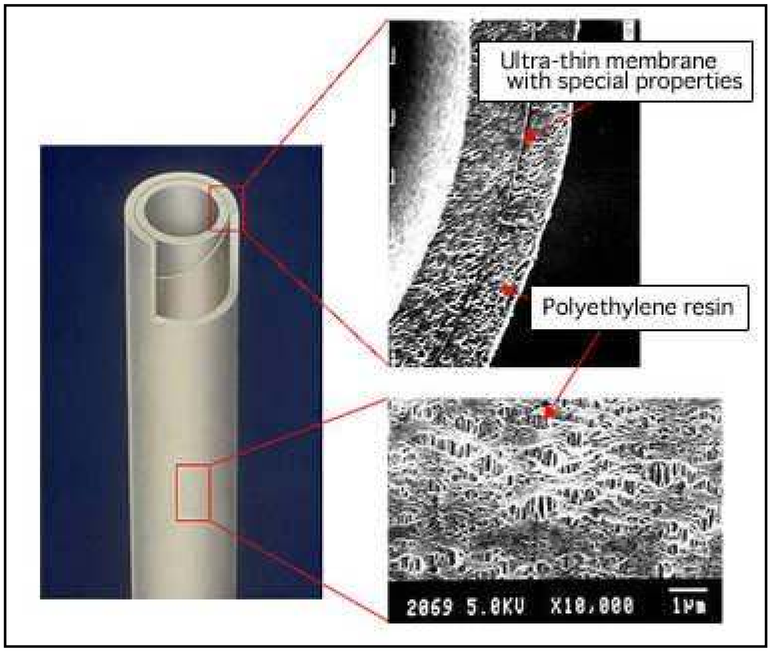


Figure 2.6: Non-porous membrane structure (Rayon, 2004)

2.3.2 Asymmetric Membrane

A membrane having different chemical and physical structures in direction of thickness was called an asymmetric or anisotropic membrane. This structure was characterized by a non uniform structure comprising an active top layer or skin supported by a porous support or sub – layer. Three types of asymmetric membrane were: porous, porous with top layer and composites (Scott, 1998). A cross section of asymmetric membrane was showed in Figure 2.7.

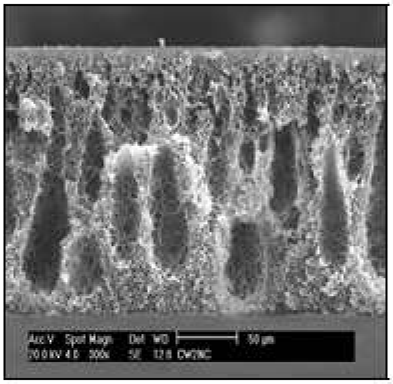


Figure 2.7: Cross section of asymmetric membrane (Ismail *et al.*, 2004)

2.3.2.1 Composites membrane

A membrane composed of more than one kind of material was called a composite membrane. There are three group of composite membrane; laminate membranes, which are laminated with more than two kinds of membranes; a coated membrane which was made by evaporating a solvent after coating the heterogeneous polymeric solution on a membrane surface; and a plasma membrane, which made by chemically combining heterogeneous organic substances using plasma (Wang *et al.*, 2006). The advantage and disadvantage of different membrane were shown in Table 2.1.

Table 2.1: Advantages and disadvantages of different membranes (Simon *et al*, 2003)

Membrane	**Advantages**	**Disadvantages**
Cellulose acetate	-Good permeability and rejection characteristics -Susceptible to hydrolysis -Chlorine tolerant and fouling resistant	Limited pH resistance
Polyethersulfone, polysulfone, polyacrylontrile, polyvinylidenefuoride	-Ability to modify properties through polymer brand -Good strength and permeability -PVDF best for flexibility and use with air scour -PES best for polymer blending and UF rating	—
Polyethylene, polypropylene	Susceptible to oxidation	Limited blend capability

2.4 Membrane Separation Processes

Membrane technology was one of the most emerging technologies now a days. The membrane processes are used in a wide range of application. One of the examples was in the hydrogen recovery in refineries. The membrane permeate was the portion of the fluid that has passed through the semi-permeable membrane whereas the concentrate stream contains the constituents that have been rejected by the membrane (Baker, 2001). Figure 2.8 showed the typical membrane separation process diagram.

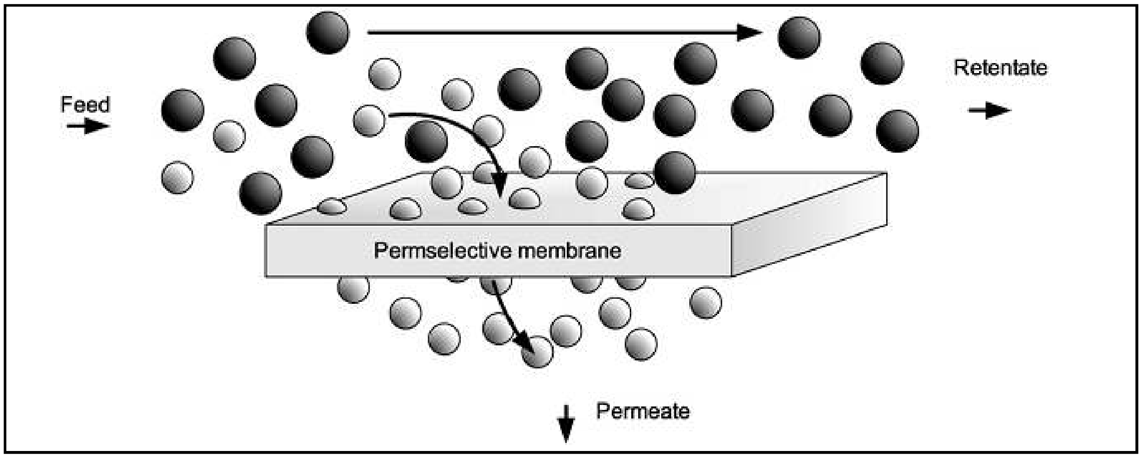


Figure 2.8: Simple schematic diagram of membrane separation process (Lu. *et al*., 2007)

2.4.1 Electrodialysis

Electrodialysis was an electro-membrane process in which ions were transported through a membrane from one solution to another under the influence of an electrical potential. This separation process can be utilized to perform several types of separations such as separation and concentration of salts, acid and bases from aqueous solution or the separation and concentration of monovalent ions from multiple charged components or the separation of ionic compounds from uncharged molecules. The system consists two kinds of membrane, the cation and anion which were placed in an electric field. An anion-selective membrane permits only the anions and cation-selective membrane permits only the cations. The transport of ions across the membranes results in ion depiction in some cells, and ion concentration in alternate ones. Electrodialysis widely use for production of potable water from sea or brackish water, electroplating rinse recovery, desalting of cheese whey, production of ultrapure water and etc (Gray, 2005). The electrodialysis process showed in Figure 2.9.

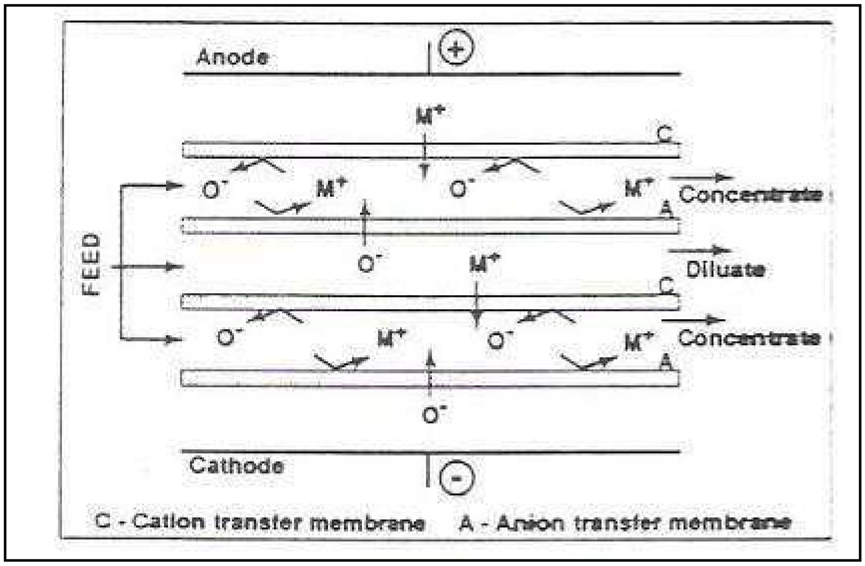
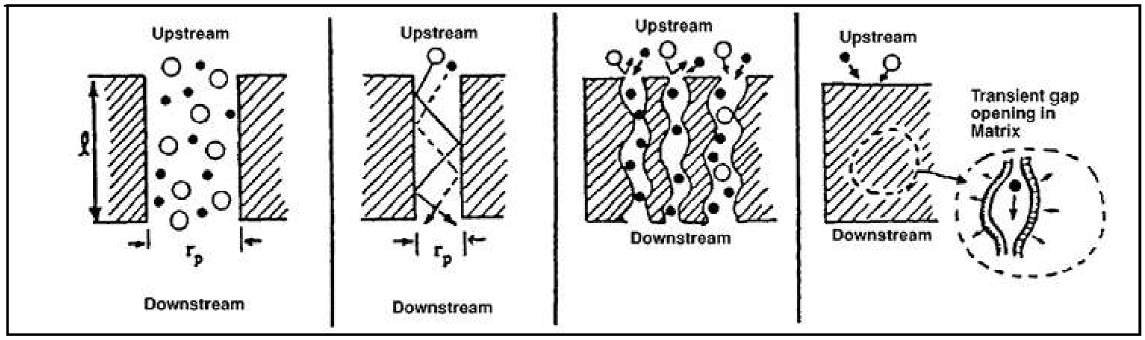


Figure 2.9: Electrodialysis membrane process (Scott, 1998)

2.4.2 Gas Permeation In A Membrane

The membrane used in this separation is made of polymers and copolymers in the forms of flat film or hollow fiber. In this process, the different gases passes through certain membranes at significantly different rates, thus permitting a partial separation. There is generally four molecular transport mechanism through membranes; (i) viscous flow, (ii) Knudsen flow, (iii) micropore molecular sieving, (iv) solution diffusion regime (Lu *et al*., 2007).

In viscous flow, no separation was achieved. Knudsen flow applies when the pore radius is smaller than the gas molecule's mean free path in a separation. In micropore molecular sieving, separation based on the much higher diffusion rates of the smallest molecules. Solubility and mobility is main factor in solution-diffusion regime. Smallest molecule is only favors in diffusivity selectivity. Solubility selectivity favors the most condensable molecule (Freemantle, 2005). These four types of mechanism are shown in Figure 2.10.



(a) viscous flow (b) Knudsen flow (c) molecular sieving (d) solution-diffusion
(Lu *et al.*, 2007)

Figure 2.10: Types of molecular transport mechanism

The schematic diagram of gas permeation in membrane was shown in Figure 2.11.

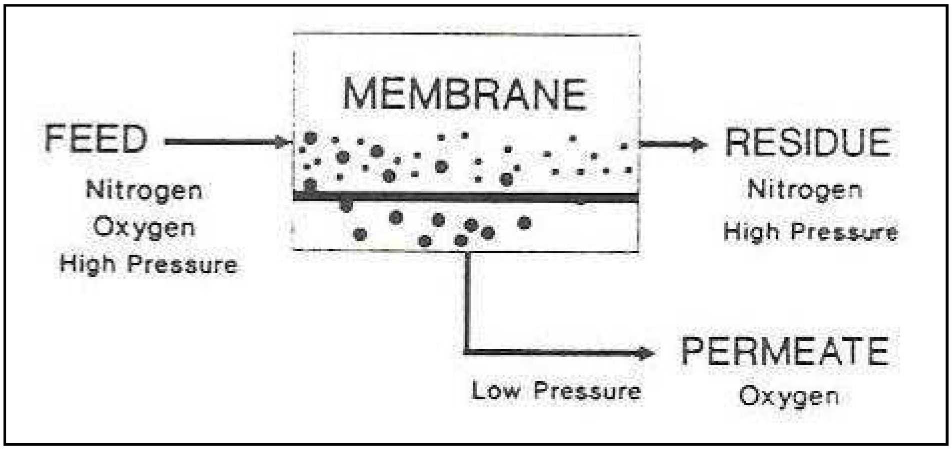


Figure 2.11: Gas permeation membrane process (Scott, 1998)

2.4.3 Reverse Osmosis

Reverse osmosis can be termed as a water treatment process that removes undesirable materials from water by using pressure to force water molecules through a semi-permeable membrane. The pressure forces the water to flow in reverse direction to the flow direction in natural osmosis. Reverse osmosis was also called “hyperfiltration”. In reverse osmosis, solutes and solids was swept away with the concentrate stream, eliminating frequent membrane filter change. Reverse osmosis widely applied to aqueous stream at ambient temperature. Some of application using reverse osmosis was in biomedical application, laboratory application, kidney dialysis, hemodialysis and etc (Amjad, 1993). Figure 2.12 shows the schematic diagram of reverse osmosis.

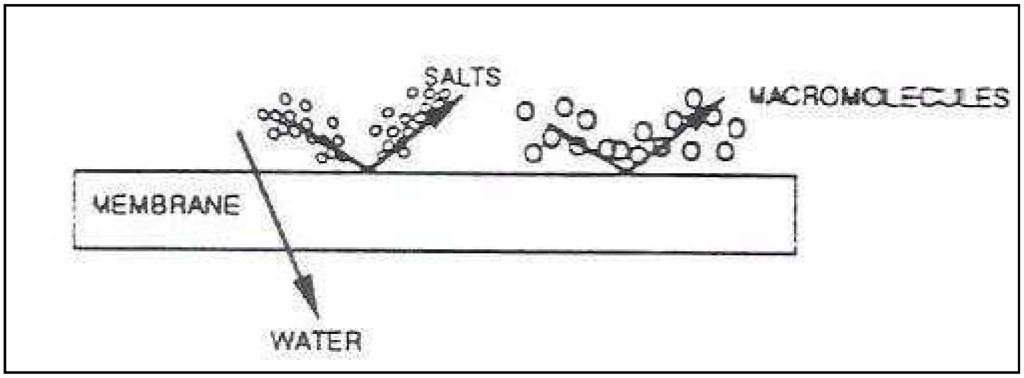


Figure 2.12: Reverse osmosis membrane process (Scott, 1998)

2.4.4 Ultrafiltration (UF)

Ultrafiltration was a membrane process lies between nanofiltration and microfiltration. In ultrafiltration, asymmetric porous membrane was widely used. The thickness of this membrane usually in a range of 150 µm with pore sizes of 1-100 nm. Pressure was the driving force in this process. The main application of this process applied to food industrial, textile, pharmaceutical, automotive and water treatment (Cheryan, 1998).

UF usually implies separation of macromolecules such as protein from low molecular weight solvents. Pores in the support layer of the membrane were relatively larger than those of the surface layer. Material passing into fine pores can readily be transported through the open-celled, sponge-like structure of the support layer. It was found that, whenever the solvent of a mixture flows through the membrane, retained species are locally concentrated at the membrane surface, thereby resisting the flow. In the case of processing solution, this localized concentration of solute normally results in precipitation of a solute gel over the membrane. When processing a suspension, the solids collect as a porous layer over the membrane surface (Zeman *et al*., 1996). Figure 2.13 shows the schematic diagram of ultrafiltration process.

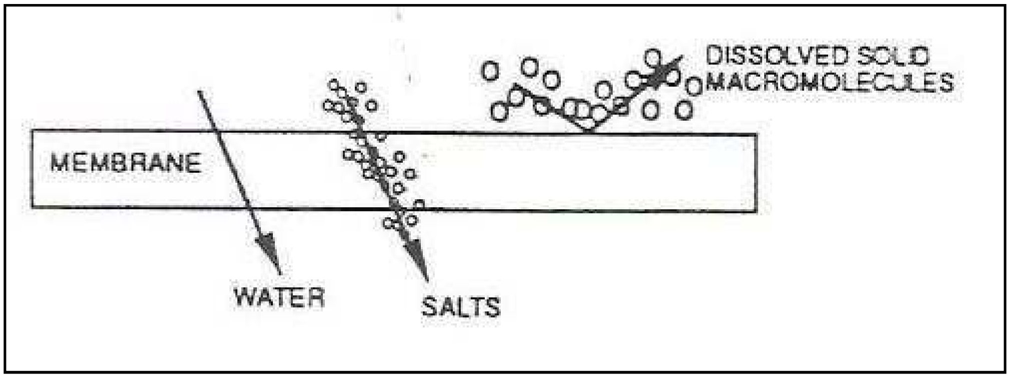


Figure 2.13: Ultrafiltration membrane process (Scott, 1998)

2.4.5 Microfiltration (MF)

In order to separate micron-size particles from fluids, the pressure-driven flow through the membrane was used. This applied to microfiltration membrane process. The particles are usually larger than those in ultrafiltration. Microfiltration was a process separating material of colloidal size and larger than true solutions. A MF membrane was generally porous enough to pass molecules of true solutions, even if they are large. Microfilters can also be used to sterilize solutions, as they were prepared with pores smaller than 0.3 microns, the diameter of the smallest bacterium, pseudomonas diminuta. This technology offers membranes with absolute rating, which highly desirable for critical operations such as sterile filtration of parental fluids, sterile filtration of air and preparation of particulate, free-water for the electronics industry. This process was widely used in food and beverage, chemical industry, fermentation field and laboratory uses (Zeman et al., 1996). The diagram of this process can be seen in Figure 2.14.

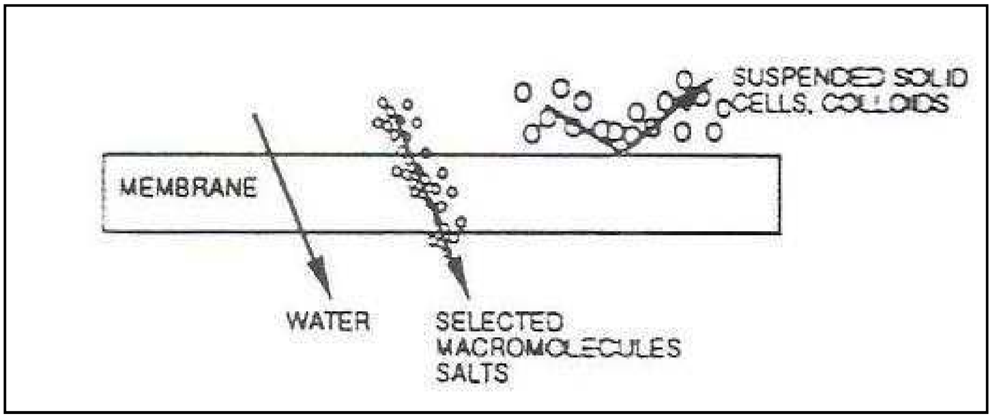


Figure 2.14: Microfiltration membrane process (Scott, 1998)

2.4.6 Pervaporation

Pervaporation was a membrane process in which a pure liquid or liquid mixture was in contact with the membrane on the feed or upstream side at atmospheric pressure and where the permeate was removed as a vapour because of a low vapour pressure existing on the permeate or downstream side. This low vapour pressure can be achieved by employing a carrier gas or using a vacuum pump. The downstream pressure must be lower than the saturation pressure at least. The pervaporation process involved three steps; selective sorption into the membrane on the feed side, selective diffusion through the membrane and desorption into a vapour phase on the permeate side (Mulder, 1996). In this process due to its complexity, mass transfer and heat transfer was applied. Some application using this process technique was separation of fermentation products and dewatering the inorganic fluids (Matsuura, 1994). Figure 2.15 shows this membrane processes.

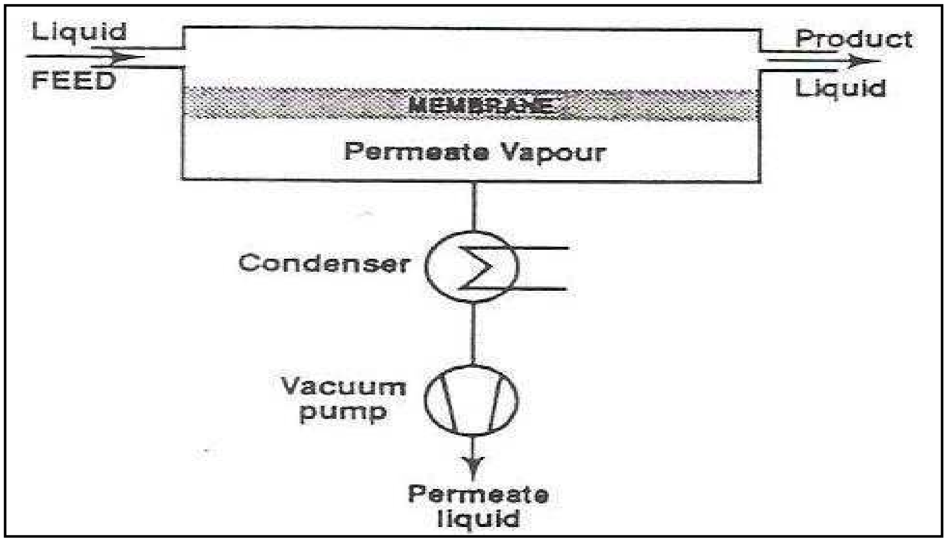


Figure 2.15: Pervaporation membrane process (Scott, 1998)

The summary of the characteristics of membranes used in different membrane separation processes, process driving forces and applications of such processes is tabulated in Table 2.2.

Table 2.2: The characteristics of membranes used in different membrane separation processes, process driving forces and applications of such processes (Scott, 1998)

Process	**Membrane type and pore radius**	**Membrane material**	**Process driving force**	**Application**
Microfiltration	Symmetric microporous, 0.1-10 microns	Cellulose nitrate or acetate, Polyvinylidene difluoride (PVDF), Polyamides, Polysulfone, PTFE, Metal Oxides etc.	Hydro-static pressure difference at approx. 10-500 kPa	Sterile filtration, Clarification
Ultrafiltration	Asymmetric microporous, 1-10 nm	Polysulfone, Polypropylene, Nylon 6, PTFE, PVC, Acrylic Copolymer	Hydrostatic pressure difference at approx. 0.1-1.0 Mpa	Separation of macromolecular solutions
Reverse Osmosis	Asymmetric skin-type, 0.5-1.5 nm	Polymers, Cellulosic acetate, Aromatic Polyamide	Hydrostatic pressure difference at approx. 2-10 Mpa	Separation of salts and microsolutes from solutions
Electrodialysis	Cation and anion exchange membrane	Sulfonated cross-linked polystyrene	Electrical potential gradient	Desalting of ionic solutions
Gas Separation	Asymmetric homogeneous polymer	Polymers & copolymers	Hydrostatic pressure and concentration gradients	Separation of gas mixtures
Pervaporation	Asymmetric homogenous polymer (A non-porous membrane)	Polyacrylonitrile, Polymers	Vapour pressure gradient	Separation of azeotropic mixtures

2.5 Advantages and Disadvantages of Membrane Separation Process

There were advantage and disadvantage for every separation process based on the economic, environment and engineering. The pros and cons of membrane separation process have been summarized in Table 2.3.

Table 2.3: Advantages and disadvantages of membrane separation process (David *et al*., 1999)

Advantages	**Disadvantages**
• Membrane separation consistently separates a wide variety of emulsion, surfactant, and chelating chemistries and various mixtures.	• Membranes are expensive
• It requires no specific chemical knowledge.	• Certain solvents can quickly and permanently destroy the membrane.
• Complex instrumentation is not required.	• Certain colloidal solids, especially graphite and residues from vibratory deburring operations, can permanently foul the membrane surface.
• Reducing process materials requirement.	• The energy cost is higher than chemical treatment, although less than evaporation.
• Minimizing waste disposal costs.	• Oil emulsions are not "chemically separated," so secondary oil recovery can be difficult.
• Appreciable energy savings	• Synthetics are not effectively treated by this method.
• Environmentally benign	
• Clean technology with operational ease	
• Replaces the conventional processes like filtration, distillation, ion-exchange and chemical treatment systems.	
• Greater flexibility in designing systems.	

2.6 Gas Separation Using Membrane

Membrane technology for separating gases was likely to play an increasingly important role in reducing the environmental impact and costs of industrial processes due to risen of energy costs. Over the separation technologies, gas separation using membrane offer a number of benefits. Currently, the most widely used membrane materials for gas separation are polymers. It was attractive as membranes due to its high surface area and it low cost of manufacturing the fibers makes them of interest for large – scale industrial application (Richard Baker, 2001).

Besides of conventional technologies such as cryogenic distillation of air, condensation of organic vapors removal from gas mixture and amine absorption was used to remove acid gases required a phase change in order to separate gas mixture. This however, adds significant energy cost to the separation cost. Fortunately, for membrane gas separation, the process does not required phase change and this was one of the advantages of the membrane technology. In addition, gas separation membrane units were smaller than other types of plants and therefore it has small footprints. A small footprint was important in environments such as offshore gas-processing platforms (Freemantle, 2005). Gas separation membranes are most widely used in industry for hydrogen separation, for example, hydrogen/nitrogen separation in ammonia plants and hydrogen/hydrocarbon separations in petrochemical applications, separating nitrogen from air, CO_2 and water removal from natural gas and organic vapor removal from air or nitrogen streams.

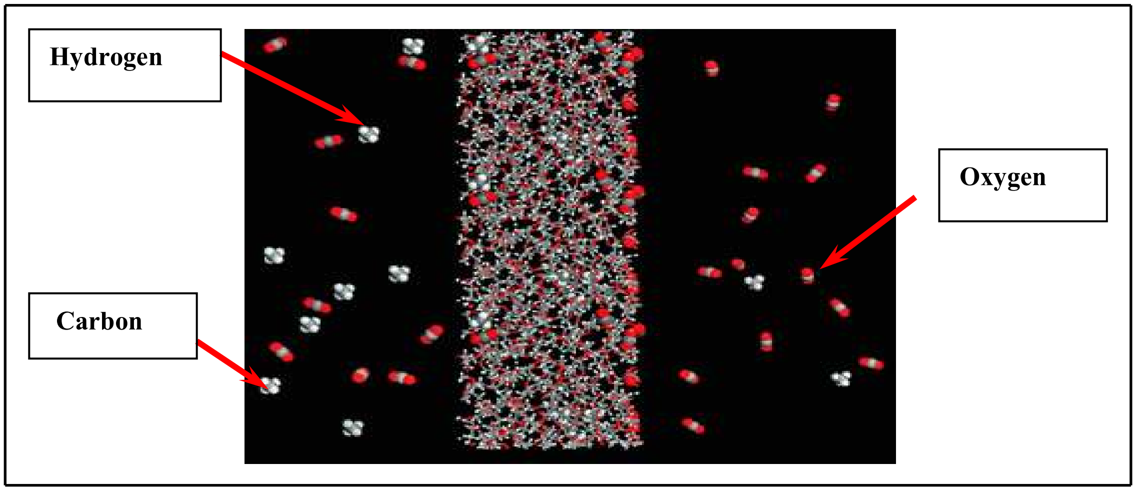


Figure 2.16: Solubility-selective polymer membrane developed by Freeman's group removes CO_2 from CO_2/CH_4 mixture (Freemantle, 2005).

2.7 Membrane For Gas Separation

Polymeric membranes are membranes that are made of polymer materials such as polysulfone, polyethersulfone and polyimide which commonly known as rubbery materials. This membrane was frequently used because they exhibit much better selectivity's rather than glassy polymers. Rubbery polymers often cross linked for separation of organic vapours from air. This type of chain structure causes elastomers to posses memory thus becomes rigid and brittle. It currently commercially available operates according to the solution-diffusion mechanism. The important feature of polymeric membrane was the ability to control different species. Polymeric membranes has been used in membrane gas separation was a proven of technology and widely used in industrial application. Key industrial applications includes: oxygen-nitrogen separation, removal of organics and natural gas enrichment. Figure 2.17 showed the polymeric membrane structure.