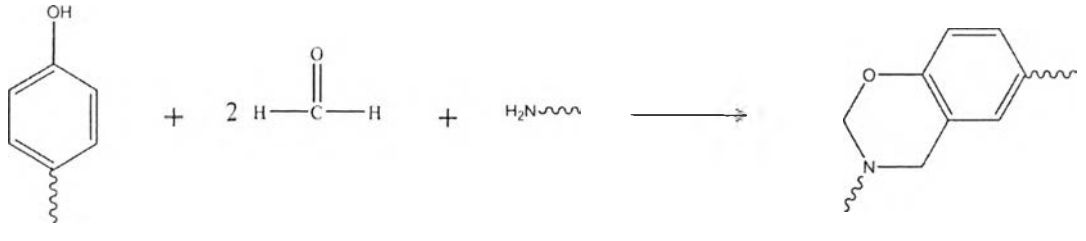
# CHAPTER I
# INTRODUCTION

## 1.1 Introduction to Polybenzoxazine

Polybenzoxazine is a new class of phenolic resins which is very accepted and useful in polymer research. There are three common types of chemical needed to synthesize polybenzoxazine, including various aromatic/aliphatic amines, mono/diphenols, and formaldehyde, as shown in Scheme 1.1. Accordingly, phenol and amine could be varied and this is one of the most advantages of polybenzoxazine in excellent molecular design flexibility. The preparation of polybenzoxazine is also easy and low cost. Moreover, polybenzoxazine has good properties in high glass-transition temperature ($T_g$), high thermal stability, good mechanical properties, and low shrinkage upon polymerization thermal stability (Ning *et al.*, 1994).




**Scheme 1.1** Simple synthesis reaction of polybenzoxazine

## 1.2 Membrane Separation

Technology in separation using membrane is well-known, essential, and rapid growth during the last few decades in the separation process. Membrane is a kind of barrier to separate liquid–liquid or gas–gas in feed side. The separation could occur by the functionality of the membrane which, for a binary system, permits one constituent to pass through, called permeate, but still retains the other in feed side, called retentate. The system is worked on the basis of the difference in physical and chemical properties between the membrane and permeating component. However, it

is also depended on the operating conditions in the separation process, including concentration, vapour pressure, hydrostatic pressure, electrical potential or temperature.

### 1.3 Pervaporation

Pervaporation is a technique to separate closely boiling point substances. The membrane is the key for separating the components. One component in the feed side will go through the membrane as vapour by using membrane selectivity and vacuum pressure in permeate side, as shown in Figure 1.1. Generally, at a good condition, there is only one substance going through the membrane. Pervaporation is also used in the dehydration of organic solvents, the removal of organics from aqueous, and the separation of heat sensitive products. The importance character of this process is low energy consumption due to operation at low temperature. The performance of the membrane in the pervaporation process is determined by using separation factor and permeation flux calculated from the amount of the component permeated per unit area per time.

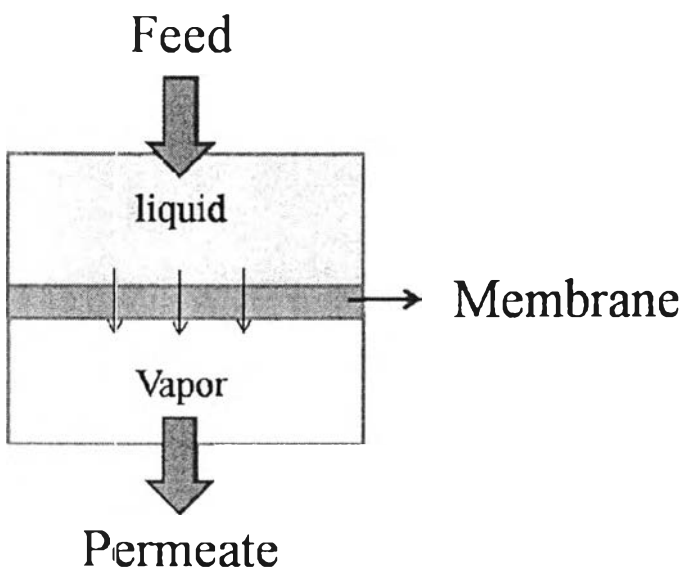



**Figure 1.1** Overview of pervaporation

## 1.4 Gas Separation Process

Gas separation is applied to purify gas before using in many gas industries, especially natural gas processing plant, containing various types of gas. The composition of natural gas is mainly composed of methane which is wildly used as fuel. However, carbon dioxide and sulfur dioxide are also contained in the natural gas, and these two gases are acid gas that can break some parts of instrument in the process. Removal of the acid gas is thus necessary before using methane, and membrane is a good choice for gas separation because of high selectivity, low energy consumption, low cost, simple to prepare, modify, and process.

## 1.5 Static Light Scattering

Static light scattering technique is a technique used to measure the intensity at many angles of the scattered light for obtaining molecular weight ($M_w$) and radius of gyration ($R_g$) of macromolecules like polymers. The most common equation to measure $M_w$ is Zimm equation:

$$\frac{Kc}{\Delta R(\theta,c)} = \frac{1}{M_w P(\theta)} + 2A_2c = \frac{1}{M_w}\left(1 + \frac{q^2 R_g^2}{3}\right) + 2A_2c \qquad (1.1)$$

Where, $K = \frac{4\pi^2 n^2 \left(\frac{dn}{dc}\right)^2}{N_A \lambda^4}$, $\Delta R(\theta, c) = R_A(\theta) - R_0(\theta)$

$$q = \left(\frac{4\pi n}{\lambda}\right)\sin\theta \,, R(\theta) = \frac{I_A(\theta) n_0^2 R_T}{I_T(\theta) n_T^2}$$

## 1.6 Dynamic Light Scattering

Dynamic light scattering (photon correlation spectroscopy, quasi elastic light scattering) is a method to determine size distribution profile of small particles in suspension or polymers in solution. When small particles are hit by light and make the light scatter in all direction is called Rayleigh scattering. Brownian motion is present when laser is used as light source which shows a time-dependent fluctuation in the scattering intensity. Generally, most polymers are heterodisperse, polydisperse,

or multimodal systems, like polybenzoxazine, thus, CONTIN, a general program package for solving equation of autocorrelation function by Provencher S. W. (1982), as shown in eq. 1.2, is employed

$$g^1(q;\tau) = \int G(\Gamma) \exp(-\Gamma\tau)\, d\Gamma \qquad (1.2)$$

## 1.7 Objectives

Therefore, in this study we illustrate how various polybenzoxazine membranes are synthesized and used for separating water from the 10:90 ethanol-water mixture via the pervaporation technique. Polybenzoxazine membrane is also introduced to study the separation of $CO_2/CH_4$ gas mixture. Moreover, the properties of benzoxazine solution, viz. $M_w$, $R_g$ and $R_h$, are studied as a function of time using static and dynamic light scattering methods.