CHAPTER I

INTRODUCTION

Freeze concentration is an effective method to concentrate a solution by freezing a solvent and then separating it from the remainder (or a solute). The process has been employed to concentrate fruit juices and dairy products, to pre-concentrate coffee extracts before freeze-drying, to pre-concentrate a number of solutes for analytical purposes, and to desalinate seawater and wastewater (Muller, 1967; Ramteke *et al.* 1993; Hartel, 1992). This method is operated at low temperatures; thus, there are no heat-induced changes. Accordingly, this method is considered to be suitable for concentrating liquid food with high flavor retention or thermally fragile compounds (Muller, 1967; Schwartzberg, 1977).

At industrial scales, the suspension crystallization method has been extensively used because of its adaptability for scale up. This system, however, is complicated because the whole process comprises ice nucleation, ice crystal growth, and ice-crystals separation processes. Furthermore, the capital cost of the system is very expensive. Consequently, the practical applications of this method are limited (Deshpande, Bolin, and Salunkhe 1982; Ramteke *et al.*, 1993; Hartel and Epinel, 1993).

Progressive freeze-concentration is one of the freeze-concentration techniques. In this process, only a single ice crystal is formed in the system. When compared to the conventional suspension crystallization method, progressive freeze-concentration provides an ease of separation of ice crystal from the concentrated solution. In addition, the whole system can be simplified in order to reduce the cost of the freeze concentration (Bae, Miyawaki, and Arai, 1994; Liu, Miyawaki, and Hayakawa, 1999).

An investigation of the efficiency of the progressive freeze-concentration process on model solutions containing glucose and blue dextran, carried out by Liu, Miyawaki, and Nakamura (1997), showed that the operating conditions, such as the stirring speed near ice-solution interface and the advance rate of the ice front, affected the efficiency of the process. Miyawaki *et al.* (1998) theoretically analyzed the effective partition coefficient of solutes between the ice and the liquid phases in the progressive freeze-concentration using the concentration of polarization model. They found that the effective partition coefficient of solutes at the liquid-ice interface is an important parameter in the progressive freeze-concentration process. However, only a few studies have been done previously to investigate the factors affecting the effective partition coefficient, which include the initial concentration of a solute, the type of solute (either non-ionic or ionic solute), and the type of solution (either true or colloidal solution).

In this research, the efficiencies of the progressive freeze-concentration process on model solutions including ionic, non-ionic, and colloidal solutions were determined. A limiting partition coefficient at the liquid-ice interface was introduced to evaluate the efficiency of the progressive freeze concentration. The limiting partition coefficient is the partition coefficient of a solution at the ice-liquid interface observed either at the infinitesimal advance rate of ice front or at the infinite mass transfer rate through the interface. The determination of the limiting partition coefficient based on a concentration polarization model was proposed. The effects of operating conditions, initial concentration, and properties of solutes on the limiting partition coefficient were also discussed.

1.1 Objectives

The principal objectives of this research were:

1) to determine the limiting partition coefficient of various kinds of solutes in the progressive freeze-concentration;

2) to investigate the factors affecting the efficiency of the progressive freeze concentration in a true solution (either ionic or non-ionic solution); and

3) to investigate the factors affecting the efficiency of the progressive freeze concentration in a colloidal solution.