Chapter 13

Membrane Separation Processes

# 13.1 Introduction and Types of Membrane Separation Processes

## 13.1A Introduction

## 13.1B Classification of Membrane Processes

### 1. Gas diffusion in porous solid.

### 2. Gas permeation in a membrane

### 3. Liquid permeation or dialysis

### 4. Reverse osmosis

### 5. Ultrafiltration membrane process

### 6. Gel permeation chromatography

# 13.2 Liquid Permeation Membrane Processes or Dialysis

## 13.2A Series Resistances in Membrane Processes

Figure 13.2-1: Concentration profiles for membrane processes: (a) two liquid films and a solid, (b) two gas films and a solid.

13.2-1:

13.2-2:

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13.2-4:

13.2-5:

13.2-6:

#### *Example 13.2-1: Membrane Diffusion and Liquid Film Resistances*

Figure 13.2-2: Concentrations for Example 13.2-1.

13.2-7:

## 13.2B Dialysis Processes

## 13.2C Types of Equipment for Dialysis

## 13.2D Hemodialysis in Artificial Kidney

#### *Example 13.2-2: Dialysis to Remove Urea from Blood*

# 13.3 Gas Permeation Membrane Processes

## 13.3A Series Resistances in Membrane Processes

13.3-1:

13.3-2:

13.3-3:

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## 13.3B Types of Membranes and Permeabilities for Separation of Gases

### 1. Types of membranes

### 2. Permeability of membranes

## 13.3C Types of Equipment for Gas Permeation Membrane Process

### 1. Flat membranes

#### *Table 13.3-1: Permeabilities of Various Gases in Membranes*

### 2. Spiral-wound membranes

### 3. Hollow-fiber membranes

Figure 13.3-1: Spiral-wound elements and assembly

Figure 13.3-2: Local gas flow paths for spiral-wound separator

Figure 13.3-3: Hollow-fiber separator assembly

## 13.3D Introduction to Types of Flow in Gas Permeation

### 1. Types of flow and diffusion gradients.

### 2. Assumptions used and ideal flow patterns

Figure 13.3-4: Ideal flow patterns in a membrane separator for gases: (a) complete mixing, (b) cross-flow, (c) countercurrent flow, (d) co-current flow

# 13.4 Complete-Mixing Model for Gas Separation by Membranes

## 13.4A Basic Equations Used

13.4-1:

13.4-2:

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Figure 13.4: Process flow for complete mixing case

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## 13.4B Solution of Equations for Design of Complete-Mixing Case

13.4-10:

#### Example 13.4-1: Design of a Membrane Unit for Complete Mixing

13.4-11:

#### Example 13.4-2: Membrane Design for Separation of Air

## 13.4C Minimum Concentration of Reject Stream

13.4-12:

#### Example 13.4-3: Effect of Feed Composition on Minimum Reject Concentration

# 13.5 Complete-Mixing Model for Multicomponent Mixtures

## 13.5A Derivation of Equations

13.5-1:

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## 13.5B Iteration Solution Procedure for Multicomponent Mixtures

#### Example 13.5-1: Design of Membrane Unit for Multicomponent Mixture

# 13.6 Cross-Flow Model for Gas Separation by Membranes

## 13.6A Derivation of Basic Equations

Figure 13.6-1: Process flow diagram for cross-flow model

13.6-1:

13.6-2:

13.6-3:

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13.6-5:

## 13.6B Procedure for Design of Cross-Flow Case

#### Example 13.6-1: Design of a Membrane Unit Using Cross-Flow

Table 13.6-1: Calculated Values for Example 13.6-1

13.6-6:

# 13.7 Countercurrent-Flow Model for Gas Separation by Membranes

## 13.7A Derivation of Basic Equations

13.7-1:

13.7-2:

13.7-3:

13.7-4:

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Figure 13.7-1: Flow diagram for the countercurrent-flow model

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## 13.7B Solution of Equations for Countercurrent Flow

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13.7-17:

13.7-18:

13.7-19:

13.7-20: