

# CONTENTS

List of Symbols	xix
<b>CHAPTER 1. INTRODUCTION</b>	<b>1</b>
1.1 Automation in a Chemical Laboratory	
1.2 Automation of Serial Assays	4
1.3 Discrete Analyzers	7
1.4 Continuous-Flow Analyzers	9
<b>CHAPTER 2. PRINCIPLES</b>	<b>15</b>
2.1 Flow Injection Analysis	15
2.1.1 Principles of FIA and Function of a Flow System	19
2.1.2 FIA Readouts and Peak Dimensions	21
2.2 Dispersion of the Sample Zone and Design of a FIA System	23
2.2.1 Dispersion Coefficient	23
2.2.2 Peak Height and Sample Volume	26
2.2.3 Peak Height, Channel Length, and Flow Rate	28
2.2.4 Peak Height and Channel Geometry	31
2.2.5 Peak Width, Dispersion Factor, and Sampling Frequency	36
2.3 Dispersion of a Sample Zone in a Reagent Stream	39
2.3.1 Single Line	40
2.3.2 Two or Several Lines	42
2.4 FIA Gradient Techniques: Single Zone	44
2.4.1 Gradient Dilution and Gradient Scanning	47
2.4.2 Gradient Calibration	49

2.4.3	Reaction Rate Measurement by Stopped Flow on the Gradient	52
2.4.4	Peak Width and Gradient Titrations	54
2.4.5	Single Zone Yielding a Double Peak	60
2.5	FIA Gradient Techniques: Zone Merging, Zone Penetration, and Multiple Peaks	63
2.5.1	Sample Zone and Reagent Zone	63
2.5.2	Selectivity Measurement	66
2.5.3	Standard Addition	67
2.5.4	Multiple Peaks Developed by a pH Gradient	70
2.6	Scaling of FIA Systems	70
2.6.1	Concept of Similarity	70
2.6.2	Scaling Factors Applicable to FIA	71
2.6.3	Scaling and Gradients	73
2.7	Chemical Kinetics in a FIA System	74
2.7.1	Chemical Conversion at Continuous Flow	74
2.7.2	Evaluation of Conversion by Stopped-Flow FIA	79
2.7.3	Kinetic Assays, Catalytic Assays, and the Kinetic Advantage of FIA	83
<b>CHAPTER 3.</b>	<b>THEORETICAL ASPECTS OF FIA</b>	<b>87</b>
3.1	Theory of Dispersion Related to FIA	87
3.1.1	The Stimulus Response Technique	90
3.1.2	The Tanks-in-Series Model and Nonlaminar Flow	95
3.1.3	Laminar Flow and Radial Mixing in FIA	98
3.1.4	The Diffusion Model and Dispersion in a Straight Tube	100
3.1.5	Dispersion in Coiled Tubes and in 3-D Reactors	105
3.1.6	Dispersion in Packed Tubes and in an SBSR Reactor	115
3.1.7	Influence of Sample Volume	118

3.2	Chemical Kinetics in FIA Systems and Other Theoretical Aspects to be Addressed	122
3.2.1	Chemical Kinetics in Straight, Packed, and Coiled Reactors	123
3.2.2	Chemical Kinetics in a Stirred Tank	130
3.2.3	Mixing, Diffusion, and Dialysis Units; Detectors	131
3.2.4	Heterogeneous Samples; Viscosity and Surface Properties	134
CHAPTER 4.	TECHNIQUES	139
4.1	Single-Line FIA Manifolds	140
4.2	Two- and Multiline FIA Manifolds	147
4.2.1	High-Sensitivity FIA	152
4.3	Stopped-Flow FIA Measurement	156
4.4	Parallel FIA Systems	166
4.5	Intermittent Pumping and Merging Zones	172
4.5.1	Simple Merging Zones Techniques	174
4.5.2	Gradient Techniques with Injection of Two or Several Zones	177
4.6	FIA Determinations Based on Separation Processes	185
4.6.1	Solvent Extraction	186
4.6.2	Gas Diffusion	192
4.6.3	Dialysis	200
4.7	FIA Systems with Pretreatment of Sample in Packed Reactors	
4.7.1	On-line Preconcentration and Conversion Techniques	203
4.7.2	Immobilized Enzymes	215
4.7.3	Generation of Reagents <i>in Statu Nascendi</i>	219
4.8	FIA Methods Based on Multidetector and Multidetermination	
4.9	FIA Titrations and Peak Width Measurements	229

4.10	FIA Scanning Methods and Simplex Optimization	
4.11	Reversed FIA and Flow Reversal FIA	
4.12	Integrated Microconduits	
<b>CHAPTER 5.</b>	<b>COMPONENTS OF A FIA APPARATUS</b>	
5.1	Review of Injection Techniques	
5.1.1	Volume-Based Injection Procedures	
5.1.2	Split and Nested Sample Loops	
5.1.3	Hydrodynamic Injection	
5.1.4	Time-Based Injection Procedures	
5.2	Pumps and Other Drives	
5.3	Reactors, Connectors, and Other Manifold Components	
5.4	Detectors	
5.5	Commercially Available Flow-Injection Analyzers	
<b>CHAPTER 6.</b>	<b>EXPERIMENTAL TECHNIQUES AND FIA EXERCISES</b>	
6.1	Practical Considerations	
6.2	Starting a FIA system	
6.3	Functional Tests and Measurement of Dispersion	299
6.4	Determination of Chloride	302
6.5	Determination of Phosphate	303
6.6	High-sensitivity Determination: Relationship of Sample Volume to Peak Height	
6.7	Titration of Strong Acid with Strong Base	
6.8	Continuous Monitoring with Hydrodynamic Injection: Investigation of the Catalyzed Oxidation Process of Sulfite with Air	313
6.9	Diagnosis of Errors	317
6.9.1	Malfunction of the Apparatus	318
6.10	Closing Down a FIA System	320
6.11	FIA Laboratory—The Microconduit-Based Pedagogical System	

<b>CHAPTER 7. REVIEW OF THE FLOW-INJECTION LITERATURE</b>	<b>323</b>
7.1 FIA Throughout Its First Decade	323
7.2 Prehistory of FIA	325
7.3 Growth of Published Papers on FIA	327
7.4 Monographs and Reviews on FIA	334
7.5 Flow Analysis I, II, and III	335
Table 7.1 Theory, Methods, and Techniques Used in FIA	336
Table 7.2 Species Determined by FIA	345
Table 7.3 Flow-Injection References Listed According to Area of Application	360
<b>CHAPTER 8. FLOW INJECTION ANALYSIS NOW AND IN THE FUTURE</b>	
8.1 Serial Assays of Blood, Random Access, and Reversed Flow FIA	366
8.2 Enhancement of Instrument Response	368
8.3 Continuous Monitoring of Industrial Processes by FIA	372
8.4 Impulse Response FIA for Sensor and Material Testing	376
8.5 What Is FIA?	380
<b>LIST OF FIA REFERENCES</b>	<b>383</b>
<b>AUTHOR INDEX TO FIA REFERENCES</b>	<b>477</b>
<b>INDEX</b>	