

## TABLE OF CONTENTS

	<b>Page</b>
<b>ACKNOWLEDGEMENT</b>	III
<b>ABSTRACT IN ENGLISH</b>	IV
<b>ABSTRACT IN THAI</b>	VI
<b>TABLE OF CONTENTS</b>	VIII
<b>LIST OF TABLES</b>	XIII
<b>LIST OF ILLUSTRATIONS</b>	XV
<b>ABBREVIATIONS</b>	XVIII
<b>CHAPTER1: INTRODUCTION</b>	
1.1 Air pollution	1
1.2 Sulfur dioxide	1
1.2.1 Health and environmental effects	3
1.2.2 Atmospheric reaction of sulfur	4
1.3 Principles of gas and vapor separation	5
1.3.1 Diffusion	5
1.3.2 Adsorption	6
1.3.3 Absorption	6
1.4 Air monitoring techniques	6
1.4.1 Passive samplers	7
1.4.2 Active samplers	7

	<b>Page</b>
1.4.3 Automatic analyzers	8
1.4.4 Remote sensors	8
1.5 Passive sampling	10
1.5.1 Principle	10
1.5.2 The theory of passive sampling	14
1.6 Literature Review	16
1.7 Methods for sulfur dioxide detection	21
1.7.1 Ultraviolet fluorescence	21
1.7.2 Flame photometric detection	22
1.7.3 Gas chromatography with flame photometric detection	23
1.7.4 Colourimetry	23
1.7.5 Infrared Absorption	25
1.7.6 Coulometry	26
1.8 Ultraviolet and Visible Spectroscopy	27
1.9 Luminescence spectroscopy	30
1.9.1 Molecular fluorescence spectroscopy	30
1.9.2. Chemiluminescence	33
1.10 Research Objectives	35
<b>CHAPTER2: EXPERIMENTAL</b>	
2.1 Apparatus	36
2.2 Chemicals	36

	<b>Page</b>
2.3 Preparation of solutions	37
2.4 Optimization of method for construction of a SO <sub>2</sub> test kit	41
2.4.1 Concentration of color forming reagent	42
2.4.2 Volume of sulfamic acid	43
2.4.3 Reaction time of sulfamic acid	43
2.4.4 Volume of formaldehyde	43
2.4.5 Type of formaldehyde reagent	44
2.4.6 Reaction time of color development	44
2.5 Effect of the interferences on sulfite solution	44
2.6 Analytical characteristics	44
2.6.1 Linear dynamic range (LDR)	44
2.6.2 Calibration Curve	45
2.6.3 Limit of detection (LOD) and limit of quantification (LOQ)	45
2.6.4 Repeatability and Reproducibility	46
2.6.5 Stability of pararosaniline methyl sulfonic acid complex	46
2.7 Passive sampler for SO <sub>2</sub> determination	47
2.7.1 Configuration of passive samplers	47
2.7.2 Methodology of ambient SO <sub>2</sub> determination	48
2.7.3 Development of passive samplers	50
2.7.4 Validation of passive sampler	52
2.8 SO <sub>2</sub> test kit	53
2.8.1 Construction of a SO <sub>2</sub> test kit and user instruction	53
2.8.2 Stability of test kit reagent	55

	<b>Page</b>
2.8.3 Analysis of sulfur dioxide in air samples by SO <sub>2</sub> test kit in comparison with spectrophotometry and fluorescence techniques	55
2.8.4 Questionnaires	56
 <b>CHAPTER 3: RESULTS AND DISCUSSION</b>	
3.1 Optimization of the method for fabrication of a sulfur dioxide test kit	58
3.1.1 Optimized concentration of PRA for SO <sub>2</sub> determination	60
3.1.2 Optimized volume of sulfamic acid	64
3.1.3 Reaction time of sulfamic acid	65
3.1.4 Volume of formaldehyde	66
3.1.5 Testing of formaldehyde reagent	67
3.1.6 Reaction time of color development	68
3.1.7 Optimum methods for SO <sub>2</sub> determination	69
3.2 Effect of the interferences	70
3.3 Analytical Characteristics	71
3.3.1 Linearity range of sulfur dioxide	71
3.3.2 Calibration curve of sulfur dioxide	73
3.3.3 Limit of detection and limit of quantification	74
3.3.4 Repeatability and reproducibility of method	76
3.3.5 Stability of Complex	77
3.4 Development of passive sampler for determination of SO <sub>2</sub> in ambient air	79
3.4.1 Optimization of diffusion tube types	79

	<b>Page</b>
3.4.2 Testing of filtration of sulfite solution	81
3.4.3 Optimum sampling period of SO <sub>2</sub> in ambient air	83
3.5 Construction of SO <sub>2</sub> test kit and reliability testing	85
3.5.1 Construction of sulfur dioxide standard color chart	86
3.5.2 Stability of test kit reagent	88
3.5.3 Determination of sulfur dioxide in air by SO <sub>2</sub> test kit in comparison with spectrophotometric method and fluorescent techniques	90
3.5.4 Survey questionnaires for reliability in estimation of SO <sub>2</sub> content	91
<b>CHAPTER 4: CONCLUSION</b>	94
<b>REFERENCES</b>	98
<b>APPENDIX A</b>	106
<b>APPENDIX B</b>	109
<b>APPENDIX C</b>	115
<b>APPENDIX D</b>	116
<b>VITA</b>	117

## LIST OF TABLES

<b>Table</b>	<b>Page</b>
1.1 The chemical and physical properties of sulfur dioxide	2
1.2 Advantages and characteristics of these monitoring technologies	9
2.1 Questionnaire for survey research	57
3.1 Effects of parrosaniline concentrations on absorbance of sulfite	61
3.2 Optimization volume of sulfamic acid	64
3.3 Reaction time of sulfamic acid	65
3.4 Volume of formaldehyde and absorbance of sulfite solutions	66
3.5 Comparison type of formaldehyde reagent	67
3.6 Reaction time of color development	69
3.7 The interfering effect of sulfur dioxide	71
3.8 Linear dynamic range of sulfite standard	73
3.9 Absorbance of standard sulfite solution	74
3.10 LOD and LOQ of spectrophotometry	75
3.11 Repeatability and reproducibility of method for replicate determination of sulfite solution	76
3.12 Stability study at room temperature of sulfite solution at 0.10 mg/l	78
3.13 Types of diffusion tube and their percent difference for sulfur dioxid determination	80
3.14 SO <sub>2</sub> concentrations (ppbv) from filtrate and non filtrate process and percent loss	82

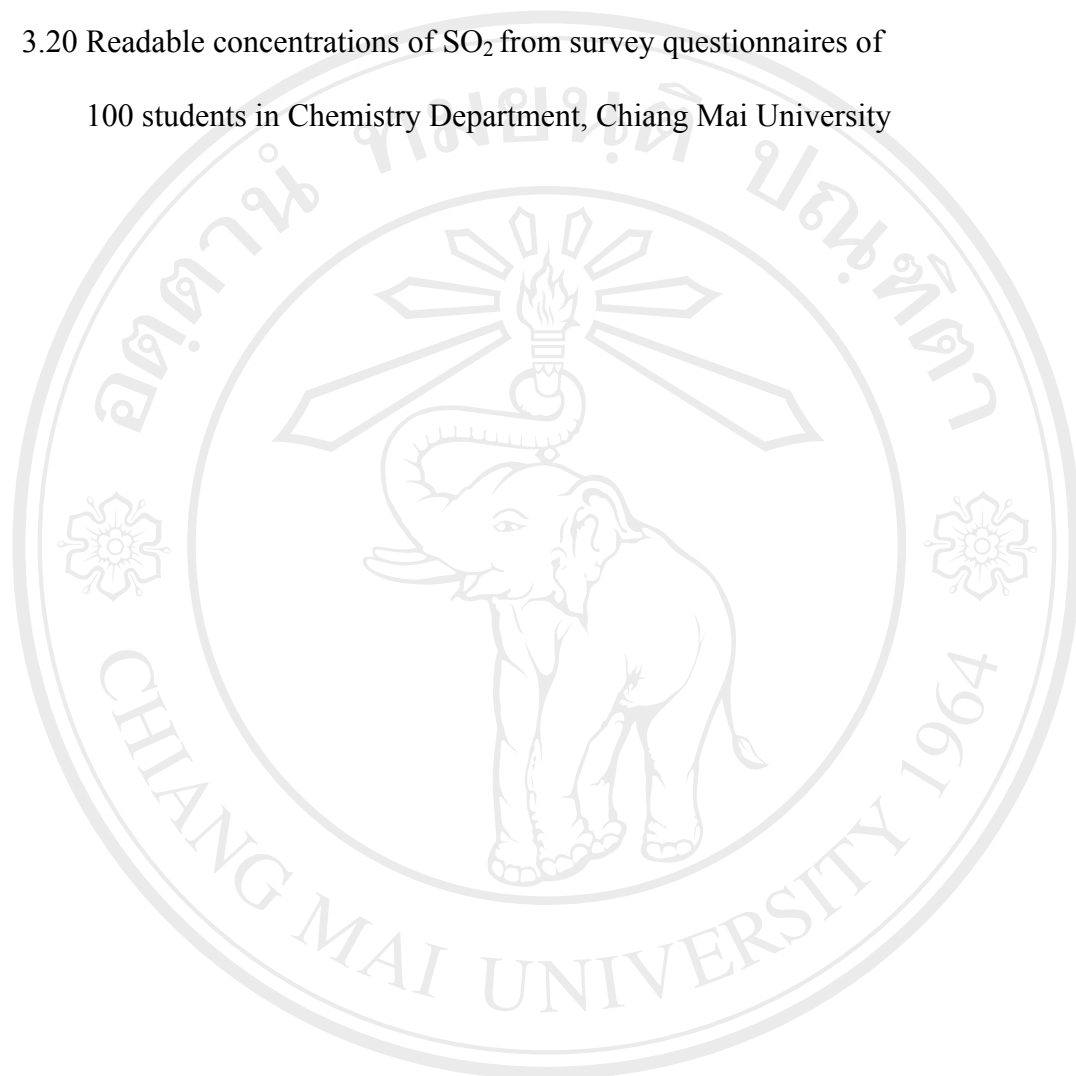
<b>Table</b>	<b>Page</b>
3.15 Filtered and non-filtered SO <sub>2</sub> concentrations from various sampling duration in comparison with fluorescent measurement	82
3.16 Sampling period and their percent difference for sulfur dioxide	84
3.17 Stability study of test kit reagents	89
3.18 Concentration of sulfur dioxide determined by sulfur dioxide test kit compared with the spectrophotometric method and fluorescence	90
3.19 Readable concentration of SO <sub>2</sub> from survey questionnaires of 100 students in Chemistry Department, Chiang Mai University	92

## LIST OF ILLUSTRATIONS

<b>Figure</b>	<b>Page</b>
1.1 Sources of sulfur dioxide	2
1.2 Schematic diagram of; (a) tube-type diffusion sampler, and (b) badge- type permeation sampler	12
1.3 Example of different sampler configurations ; (a) opened-end diffusion tube, (b) shorter diffusion tube with diffusion membrane at opening, (c) badge-type with diffusion membrane at opening, (d) double- ended badge with baffles at opening, (e) cylindrical badge with tubular diffusion membrane.	13
1.4 Transmittance of light in a spectrophotometer	28
1.5 Diagram of spectrophotometer (single beam)	29
1.6 Diagram of spectrophotometer (double beam)	30
1.7 Schematic of a fluorometer with 90° geometry	31
1.8 Fluorescence analyser for SO <sub>2</sub>	33
1.9 Chemiluminescence detector for NO <sub>x</sub>	35
2.1 Determination of SO <sub>2</sub> by the standard US EPA method	42
2.2 The configuration of passive samplers (a) and the gas diffusion pathway (b)	47
2.3 diffusion tubes (a) PE; 54 mm length and 14.8 mm i.d., (b) PP; 56 mm length and 14.8 mm i.d., (c) PP; 93 mm length and 14.8 mm i.d. and (d) PS; 98 mm length and 13.8 mm i.d.	51

<b>Figure</b>	<b>Page</b>
3.1 Effects of pararosaniline concentrations on absorbance of sulfite	62
3.2 Calibration curves of sulfite standards at different concentrations of pararosaniline; a-d. Sulfite concentration $\leq 0.10$ mg/l, e-f. Sulfite concentration = 0.20-0.80 mg/l	63
3.3 Optimization volume of sulfamic acid	65
3.4 Reaction time of sulfamic acid	66
3.5 Volume of formaldehyde	67
3.6 Linear regression obtained from buffered and non-buffered formaldehyde reagents	68
3.7 Reaction time of color development	69
3.8 Optimum methods for SO <sub>2</sub> determination	70
3.9 The interfering effect of sulfur dioxide	71
3.10 Linear dynamic range of sulfite standard	72
3.11 Calibration curve of sulfite standard solution	74
3.12 Stability study at room temperature of sulfite solution at 0.1 mg/l	77
3.13 Types of diffusion tube and compared with values from PCD monitoring station of sulfur dioxide	80
3.14 Filtered and non-filtered SO <sub>2</sub> concentrations from various sampling duration in comparison with fluorescence measurement	83
3.15 Sampling period of sulfur dioxide in ambient air	85
3.16 Sulfur dioxide test kit	86
3.17 Visual colors of sulfite solutions at different concentrations	87
3.18 Standard reference color chart of sulfur dioxide	88

Figure	Page
3.19 Stability study of test kit reagents	88
3.20 Readable concentrations of SO <sub>2</sub> from survey questionnaires of 100 students in Chemistry Department, Chiang Mai University	93

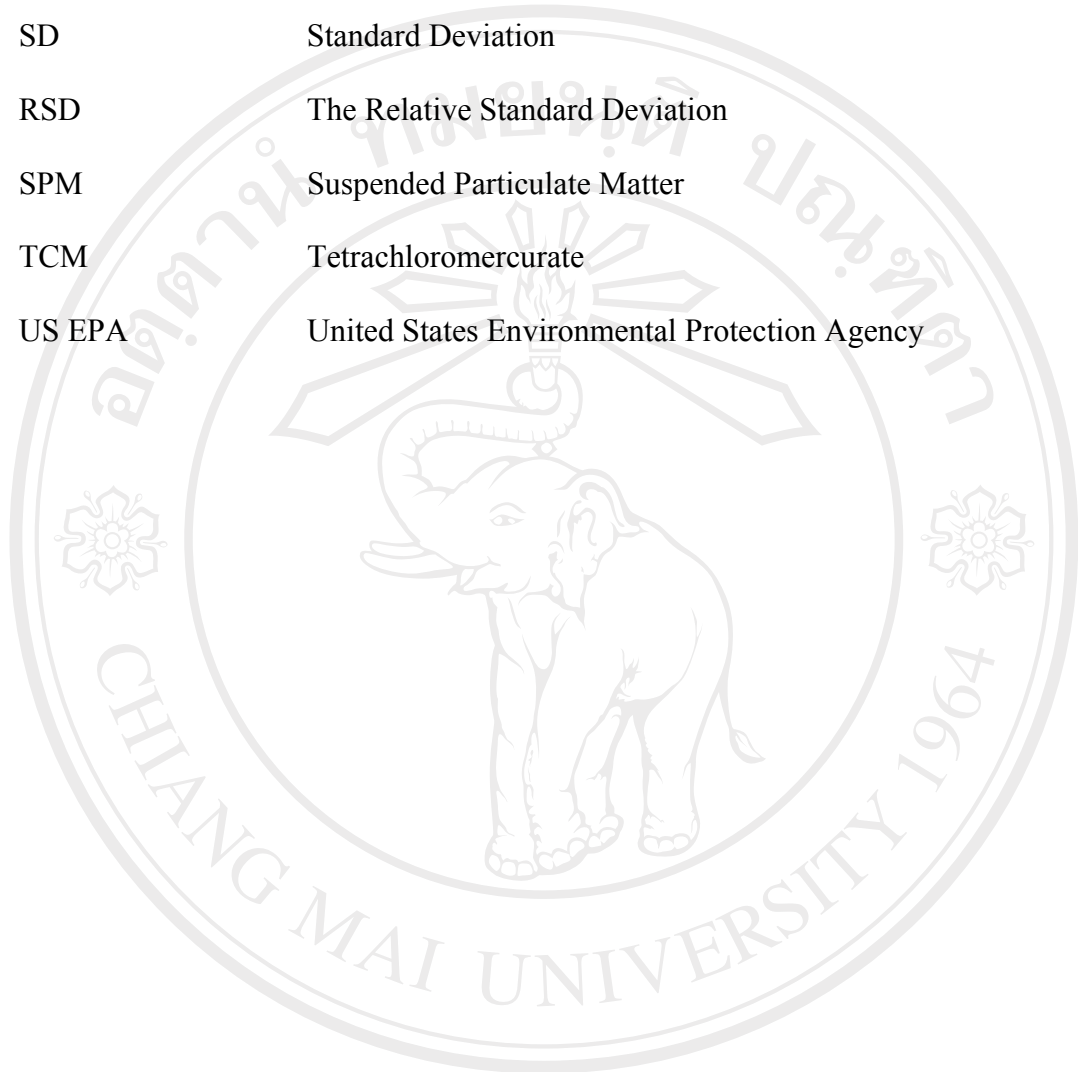


ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved

## ABBREVIATIONS

FID	Flame ionization detector
g	gram
HPLC	High Performance Liquid Chromatography
L	liter
m	meter
m/s	meter per second
μl	microliter
ml	milliliter
mg/m <sup>3</sup>	milligram per cubic meter
μg/ml	microgram per milliliter
min	minute
M	molar
MW	molecular weight
nm	nanometer
NIOSH	National Institute for Occupational Safety and Health
OSHA	The Occupational Safety and Health Administration
PCD	Pollution Control Department
ppbv	part per billion volume
ppm	part per million
PE	Polyethylene
PP	Polypropylene

PS	Polystyrene
s	second
SD	Standard Deviation
RSD	The Relative Standard Deviation
SPM	Suspended Particulate Matter
TCM	Tetrachloromercurate
US EPA	United States Environmental Protection Agency



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved