CONTENTS

	Page
Approval page	ii
Acknowledgements	iii
Abstract	iv
List of tables	viii
List of illustrations	x
Abbreviations and symbols	xii
CHAPTER 1 INTRODUCTION	
1.1 Arsenic	1
1.1.1 Information about arsenic	1
1.1.2 Arsenic in environment, exposed and effect of arsenic	5
1.1.3 Chronic arsenic poisoning in Ronpibul district,	8
Nakhon Sri Thammarat province	
1.1.4 The method for arsenic determination	10
1.1.5 Treatment technologies/removal from water	11
1.2 Activation analysis	14
1.2.1 Neutron activation analysis	14
1.2.2 Neutron source	16
1.2.3 Principle of activation analysis	17
1.2.4 Measurement of gamma ray	23
1.2.5 Quantitative determination of activity	24
1.2.6 Sensitivities for determination of elements by NAA	26
1.2.7 Preconcentration of arsenic for NAA	29
1.3 Objectives of this research	32
CHAPTER 2 EXPERIMENTAL	
2.1 Apparatus and material	33
2.1.1 Apparatus	33
2.1.2 Chemicals and materials	33
2.2 Sample material	37

2.3 NAA experiment	40
2.3.1 Preliminary study	40
2.3.1.1 Variation of pH	40
2.3.1.2 Coprecipitation yield	40
2.3.2 Qualitative analysis	41
2.3.3 Precision of the method	42
2.3.4 Percent recovery	42
2.3.5 Quantitative analysis	43
2.3.6 Detection limit	44
2.4 Calculation of results	45
CHAPTER 3 RESULTS AND DICUSSION	
3.1 Preliminary study	46
3.1.1 Variation of pH	46
3.1.2 Percent precipitation	49
3.2 Quálitative	50
3.3 Precision of the method	56
3.4 Percent recovery	59
3.5 Quantitative analysis	60
3.6 Detection limit	64
CHAPTER 4 CONCLUSION	65
CHAPTER 5 REFERENCES	67
APPENDIX A	71
APPENDIX B	72
VITA ()	73

LIST OF TABLES

Tab	ole	Page
1.1	General Informations of Arsenic	4
1.2	Arsenic concentration in the environment	7
1.3	Classification of chronic arsenic poisoning using as standard diagnosis in	9
	Thailand, 1987-1994	
1.4	Number of chronic arsenic poisoning in Ronpiboon District and other district	ets, 9
	by stage, 1987-1988	
1.5	Classification of the methods for arsenic determination	11
1.6	Examples of some techniques for arsenic determination	12
1.7	Activation analysis compared to other analytical techniques for trace	13
	elements	
1.8	Neutron capture cross section (σ_{γ}) and resonance integral (l_{γ}) (in barns)	19
	for some typical activation targets	
1.9	Half life values for typical activation products	21
1.1	0 Estimated detection limits for INAA using decay gamma rays	27
	Assuming irradiation in a reactor neutron flux of 1x10 ¹³ n cm ⁻² s ⁻¹	
1.1	1 The elements which can be analyzed by neutron activation analysis	28
	technique	
1.1	12 γ-energies of radioisotope ⁷⁶ As	32
3.1	Gamma-ray energy of radioisotopes found	50
3.2	2 Radioisotopes induced from epithermal neutron activation of elements	54
	present in coprecipitated of water samples with Pb(PDC)2 with irradiation	ı
	times = 15 minutes, cooling times = 30 minutes and measuring times = 10	0s
3.	3 The element found in water by NAA	55
3.	4 Counts of coprecipitated As-Pb(PDC) ₂ and concentration of arsenic	56
	with irradiation times = 1 hr, cooling times = 1 hr and measuring time	
	= 100 s	

3.5	Percent recovery from spiked and unspiked samples from eight	60
	individual experiment. Irradiation time = 1 hr, cooling time = 1 hr and	
	measuring time = 100 s	
3.6	Concentration of arsenic in contaminated water samples from Ronpiboon	61
	district with irradiation time =11 hr, cooling time = 13 hr and measuring	
	time = 100 s	
3.7	Concentration of arsenic in contaminated water samples from	6
	Ronpiboon district compared with other water samples from literatures	

LIST OF ILLUSTRATIONS

Figu	re	Page
1.1	Arsenic compounds	1
1.2	The effects of arsenic in drinking water. Skin damage of low arsenic	6
	poisoning in one victim.	
1.3	Diagram illustrating the process of neutron capture by a target nucleus	15
	followed by the emission of gamma rays	
1.4	A typical reactor neutron energy spectrum showing the various component	s 16
	used to describe the neutron energy regions	
1.5	Activation curve	23
1.6	Diagram shown neutron activation analysis method	29
2.1	The Thai Research Reactor (TRR-1/M1)	34
2.2	HPGe detector	35
2.3	High voltage power supply, preamplifier and amplifier	35
2.4	Computer with the Gamma Acquistion Analysis program	36
2.5	Vials	36
2.6	Rabbit	37
2.7	Map of Ronpiboon district in Nakhon Sri Thammarat province	38
2.8	Map of Moo 1-14 of Ronpiboon district in Nakhon Sri Thammarat	39
	province	
2.9	Irradiation times (Ti) and cooling times (Td) for qualitative analysis	41
	of samples	
2.	10 The standard and samples in the rabbit with 2 vials of each sample	43
	together with 3 vials of standard	
2.	11 Schematic diagram shown experiment for coprecipitation of sample	44
3.	1 A plot of count rates of 76 As(III) vs. pH, irradiation times = 15 minutes,	40
	cooling times = 20 hr and measuring times = 100 s	
3.	2 γ-spectra of ⁷⁶ As(III) induced from epithermal neutron activation	47
	after irradiation in CA2 tube: standard As(III) = 500 ppm, irradiation	
	times = 15 minutes, cooling times = 20 hr and measuring times = 100 s	

3.3	A plot of percent coprecipitation vs added standard As(III)	
3.4	γ-spectra of radioisotopes induced from epithermal neutron activation	51
	of elements present in coprecipitated of water samples with Pb(PDC)2,	
	irradiated in CA2 tube with irradiation times = 15 minute, cooling time	
	are (a) 30 minutes and (b) 3 hr, measuring time = 100 s.	
3.5	γ-spectra of radioisotopes induced from epithermal neutron activation of	52
	elements present in coprecipitated of water samples with Pb(PDC)2,	
	irradiated in CA2 tube with irradiation time = 1 hr, cooling time	
	are (a) 1 hr and (b) 3 hr and (c) 20 hr, measuring time = 100 s.	
3.6	γ-spectra of radioisotopes of induced from epithermal neutron	53
	activation of elements present in coprecipitated of water samples with	
	Pb(PDC) ₂ , irradiated in CA2 tube with irradiation time = 11 hr,	
	cooling time = 13, measuring time are (a) 100 s and (b) 1000 s.	
3.7	Gamma-spectra of induced radioisotopes after irradiation the coprecipitate	61
	As-Pb(PDC) ₂ from water sample no. 4 with epithermal neutrons in	
	CA2 tube. Irradiation time = 11 hr, cooling time = 13 hr and measuring	
	time = 100 s.	
3.8	3 Chart represents concentration of arsenic in eight contaminated water	62
	samples from Ronpiboon district, Nakhon Sri Thammarat province with	
	irradiation time = 11 hr, cooling time = 13 hr and measuring time = 100 s.	

ABBREVIATIONS AND SYMBOLS

AFS atomic fluorescence spectrometry

DGNAA delayed gamma-ray neutron activation analysis

EDXRF energy dispersive X-ray fluorescence

E-T emission transmission GFAAS

FWHM fullwidth at half maximum

FNAA fast neutron activation analysis

HG hydride-generation

HGAAS hydride-generation atomic absorption spectrometry

HPGe hyperpure (or intrinsic) germanium detector

HPLC high performance liquid chromatography
INAA instrumental neutron activation analysis

LOD limit of detect ion

MCA multi-channel analyzer

NIST the Nation Institute of Standard and Technology

NAA neutron activation analysis

PGNAA prompt gamma-ray neutron activation analysis

SRM standard reference material

TNAA thermal neutron activation analysis

RSD relative standard deviation

XRF X-ray fluorescence

A atomic weight

A₀ activity at the end of the irradiation time

A_s the saturation activity

 A_{sam} activity of sample A_{std} activity of standard

 C_{sam} count of element in sample C_{std} count of element in standard

Ci Curi

N number of nuclei

N_A	Avogadro's number
(n,γ)	(neutron, gamma) reaction
(n,p)	(neutron, proton) reaction
(n,α)	(neutron. alpha) reaction
nd	not detected
ppm	part per million
ppb	part per billion
P	branching ratio
sam	sample
std	standard
t_c	counting time
t_d	decay time
t_m	measuring time
T,t	irradiation time
\mathbf{W}_{sam}	weight of sample
W_{std}	weight of standard
W	mass of element
3	molar absorptivity
ф	neutron flux
ф _{th}	thermal neutron flux
фері	epithermal neutron flux
θ	isotopic abundance
σ	neutron cross section
$\sigma_{ ext{th}}$	thermal neutron cross section
$\sigma_{\!\scriptscriptstyle \gamma}$	neutron capture cross section
λ.	decay constant
\mathbf{l}_{y}	capture resonance integral