### Content

	Page
Acknowledgements	iii
Abstract(English)	iv
Abstract(Thai)	v
List of Table	viii
List of Figures	<b>x</b> i
Abbreviations	xv
1. Introduction	1 6
1.1 Clay minerals	1
1.2 Montmorillonite minerals	2
1.3 Transition metals	6
1.4 Chemistry of cobalt(III), cobalt(II) and nickel(II)	7
1.4.1 cobalt(III) and cobalt(II)	7 7 7 7
1.4.2 nickel(II)	9
1.5 Health and safety factors	10
1.5.1 Cobalt	10
1.5.2 Nickel	10
Aims of this research	11
	A
2. Experimental	12
2.1 Apparatus and chemicals	12
2.1.1 Apparatus	12
2.1.2 Chemicals	12
2.2 Techniques to study about properties of compound	13
2.2.1 Physical properties	13
2.2.2 Infrared spectrophotometry	13
2.2.3 Electronic spectrophotometry	13
2.2.4 Diffuse reflectance spectrophotometry	13
2.2.5 Atomic absorption spectrophotometry	14 iversity
2.2.5.1 Procedure of digestion	14
2.2.5.2 Procedure of spectroscopy	elar v e d
1. Preparation of standard calibration curve of	
Ni and Co	14
2. Preparation of sample solution for	
measurement	23

	Page
2.2.6 pH meter	23
3. Experimental and Results	24
3.1 Quanlitative study of the effect of ligands on	
nickel and cobalt-bentonite	24
3.1.1 Preparation of sample of bentonite	24
3.1.2 Result of Atomic absorption spectrophotometry	25
3.1.3 Treatment of Ni(Co) clay with ligands	25
3.1.4 Colour of clay samples	26
3.1.5 Infrared spectra	27
3.1.6 Electronic spectra	31
3.2 Typical groundwater ligands with nickel and cobalt	
bentonite /	56
3.2.1 Prepare sample of Ni-bentonite/1M and	
Co-bentonite/1M	56
3.2.2 Result of Atomic absorption spectrophotometry	56
3.2.3 Reaction with ligands	57
3.2.3.1 Reaction with equal ligand concentration	57
3.2.3.2 Infrared spectra	60
3.2.3.3 Electronic spectra	61
3.2.3.4 Reaction with various ligand concentration	73
3.2.3.5 Infrared spectra	77
3.2.3.6 Electronic spectra	79
3.2.3.7 Lability of complex nickel(II) on bentonite	81
4. Discussion and Conclusion	99 .
References	
References	103
Appendix	105
Appendix Vita Opyright by Chiang Mai	later later 116 learning 116 le
All rights res	erved

## List of Tables

Tab	ole	Page
1.1	The atomic arrangement on successive sheets of	
	montmorillonite and pyrophyllite layers	3
1.2	Physical constants of cobalt and nickel	7
2.1	Absorbance of Ni <sup>2+</sup> in the range 0.200-1.000 ppm	
	for Ni-bentonite	15
2.2	Absorbance of Ni <sup>2+</sup> in the range 0.200-1.000 ppm	
	for Ni-bentonite/1M	16
2.3	Absorbance of Co <sup>2+</sup> in the range 0.200-1.000 ppm	
	for Co-bentonite	17
2.4	Absorbance of Co <sup>2+</sup> in the range0.200-1.000 ppm	502
	for Co-bentonite/1M	18
2.5	Absorbance of Ni <sup>2+</sup> in the range 0.400-2.000 ppm	20
2.6	Absorbance of Ni <sup>2+</sup> in the range 0.400-2.000 ppm	7 7
	for study lability	21
2.7	Absorbance of Co <sup>2+</sup> in the range 0.400-2.000 ppm	22
3.1	Colour of nickel compounds and cobalt compounds	27
3.2	Infrared spectrum of Ni: NH <sub>3</sub> at various ratio	
	1:3, 1:10 and 1:25	28
3.3	Infrared spectrum of Ni: en at various ratio	
	1:1 and 1:9	28
3.4	Infrared spectrum of Ni: DMG at ratio 1:6	29
	Infrared spectrum of Ni: bipy at ratio 1:5	29
	Infrared spectrum of Co: NH <sub>3</sub> at various ratio	
	1:3, 1:10 and 1:25	29
3.7	Infrared spectrum of Co: en at various ratio	
	1:1 and 1:9	30
	Infrared spectrum of Co: DMG at ratio 1:6	U <sub>30</sub> iversity
	Infrared spectrum of Co: bipy at ratio 1:5	30
3.10	Peaks derived of Ni-bentonite treated with model	
	organic ligands in solution	31
3.11		
	organic ligands on clay surface	32

Tab.	le	Page
3.12	Peaks derived of Co-bentonite treated with model organic ligands in solution	33
3 13	Peaks derived of Co-bentonite treated with model	33
3.13	organic ligands on clay surface	24
3 1/	Colour of Ni-bentonite/1M and Co-bentonite/1M	34
J. 14		
	clays samples after treatment with solutions of organic ligands	57
2 15		57
3.13	Physical characteristic of solution remaining from	- 63 N
2 16	treatment of Ni-bentonite clays with organic ligands	58
5.10	Physical characteristic of solution remaining from	70
2 17	treatment of Co-bentonite clays with organic ligand	s 59
3.17	<i>y</i>	- 304
2 10	treatment with solution of organic ligands	60
3.18	Physical characteristic of Co-bentonite/1M after	706
2.10	treatment with solution of organic ligands	61
3.19	Peaks derived from electronic spectrum of	
	Ni-bentonite/1M treated with organic ligand	
2.20	solutions at equal concentration in solution	62
3.20	Peaks derived from electronic spectrum of	
	Ni-bentonite/1M treated with organic ligand	
	solutions at equal concentration on clay surface	62
3.21	Peaks derived from electronic spectrum of	
	Co-bentonite/1M treated with organic ligand	
	solutions at equal concentration in solution	63
3.22	Peaks derived from electronic spectrum of	
	Co-bentonite/1M treated with organic ligand	
	solutions at equal concentration on clay surface	63
3.23	Physical characteristic of Ni-bentonite/1M clay	
	samples after treatment with organic ligands at	University
	various concentration	73
3.24	Physical characteristic of Co-bentonite/1M clay	
	samples after treatment with organic ligands at	
	various concentration	74

Table	Page
3.25 Physical data from solution remaining after treatment of Ni-bentonite clays with organic ligand	
solutions at various concentration 3.26 Physical data from solution remaining after treatment of Co-bentonite clays with organic ligand	75
solutions at various concentration 3.27 Physical characteristic of Ni-bentonite/1M after treatment with organic ligands at various	76
concentration  3.28 Physical characteristic of Co-bentonite/1M after treatment with organic ligands at various	77
concentration 3.29 Peaks derived from electronic spectrum of Ni-bentonite/1M treated with various ratio of	78
organic ligands in solution 3.30 Peaks derived from electronic spectrum of Ni-bentonite/1M treated with various ratio of	79
organic ligands on clay surface 3.31 Peaks derived from electronic spectrum of Co-bentonite/1M treated with various ratio of	80
organic ligands in solution  3.32 Peaks derived from electronic spectrum of Co-bentonite/1M treated with various ratio of	80
organic ligands on clay surface  3.33 Nickel content and pH values of solution remaining after contacting Ni-bentonite with a	81
number of inorganic salt solutions	82 8 6 1 1 1
Convright by Chiang Ma	

Copyright<sup>©</sup> by Chiang Mai University All rights reserved

# List of Figures

Figu	ire F	Page
1.1	The proposed structures for montmorillonite(idealised)	3
1.2	Diagram of cobalt complexes reaction	8
2.1	Standard calibration curve of Ni <sup>2+</sup> in range 0.200-1.00	00
	ppm for Ni-bentonite	15
2.2	Standard calibration curve of Ni <sup>2+</sup> in range 0.200-1.00	0
	ppm for Ni-bentonite/1M	16
2.3	Standard calibration curve of Co <sup>2+</sup> in range 0.200-1.00	0
	ppm for Co-bentonite	17
2.4	Standard calibration curve of Co <sup>2+</sup> in range 0.200-1.00	00
٠	ppm for Co-bentonite/1M	185
2.5	Standard calibration curve of Ni <sup>2+</sup> in range 0.400-2.00	0 500
	ppm	20
2.6	Standard calibration curve of Ni <sup>2+</sup> in range 0.400-2.00	0
	ppm for study lability	21
2.7	Standard calibration curve of Co <sup>2+</sup> in range 0.400-2.00	00
	ppm	22
3.1	Infrared spectrum of Ni: NH <sub>3</sub> at various ratio	<b>-</b>
2.0	1: 3 (A), 1:10 (B) and 1:25 (C)	35
3.2	Infrared spectrum of Ni: en at various ratio	
2.2	1: 1 (A) and 1:9 (B)	36
	Infrared spectrum of Ni: DMG at ratio 1:6	37
3.4	Infrared spectrum of Ni: bipy at ratio 1:5	37
3.3	Infrared spectrum of Co: NH <sub>3</sub> at various ratio	2
20	1: 3 (A), 1: 10 (B) and 1: 25 (C)	38
3.6		20
2.7	1: 1 (A) and 1:9 (B)	39
	Infrared spectrum of Co: DMG at ratio 1:6	40 Versit
	Infrared spectrum of Co: bipy at ratio 1:5	40
3.9	Electronic spectrum of Ni: NH <sub>3</sub> at 1:3 ratio	
2 10	I = 280 - 500  nm and $II = 400 - 650  nm$	41
3.10	Electronic spectrum of Ni: NH <sub>3</sub> at 1:10 ratio	40
	I = 280 - 500  nm and $II = 400 - 750  nm$	42

Figu	re P	age
3.11	Electronic spectrum of Ni: NH <sub>3</sub> at 1:25 ratio in range 380-750 nm	43
3.12	Electronic spectrum of Ni: en at 1:1 ratio in range 220 - 320 nm	44
3.13	Electronic spectrum of Ni: en at 1:9 ratio in range 220 - 350 nm	44
3.14		45
3.15	Electronic spectrum of Ni: bipy at 1:5 ratio in	
3.16	range 190 - 320 nm Electronic spectrum of Co: NH <sub>3</sub> at 1:3 ratio in	46
3.17	range 280 - 650 nm  Electronic spectrum of Co: NH <sub>3</sub> at 1:10 ratio in	47
3.18	range 280 - 750 nm  Electronic spectrum of Co: NH <sub>3</sub> at 1:25 ratio in	47
3.19	range 280 - 700 nm  Electronic spectrum of Co: en at 1:1 ratio in	48
3.20	range 280 - 600 nm  Electronic spectrum of Co: en at 1:9 ratio in	49
3.21	range 240 - 400 nm  Electronic spectrum of Co: DMG at 1:6 ratio	49
3.22	I = 200 - 500 nm and $II = 460 - 640$ nm Electronic spectrum of Co: bipy at 1:5 ratio	50
3.23	in range 190 - 320 nm Diffuse reflectance spectrum of Ni:NH <sub>3</sub> at various ratio	51
	syn std.=synthesis standard $S_1=1:3$ $S_2=1:10$ $S_3=1:25$	52
3.24	Diffuse reflectance spectrum of Ni:en at various ratio syn std.=synthesis standard $S_1=1:1$ $S_2=1:9$	52
3.25	Diffuse reflectance spectrum of Ni: DMG syn std.=synthesis standard S=1:6	Jniversity 1
3.26	Diffuse reflectance spectrum of Ni: bipy syn std.=synthesis standard S=1:5	rved
3.27	Diffuse reflectance spectrum of Co:NH <sub>3</sub> at various rations syn std.=synthesis standard S <sub>1</sub> =1:3 S <sub>2</sub> =1:10 S <sub>2</sub> =1:25	<b>D</b>
	- avii aug aveidieais simiomid - (31271. 3 - 34271 10 - 34271 7 )	14

3.28 Diffuse reflectance spectrum of Co:en at various	
ratio syn std.=synthesis standard $S_1=1:1$ $S_2=1:9$ 54	
3.29 Diffuse reflectance spectrum of Co: DMG	
syn std.=synthesis standard S=1:6  55	
3.30 Diffuse reflectance spectrum of Co: bipy	
syn std.=synthesis standard S=1:5	
3.31 Infrared spectrum of Ni: NH <sub>3</sub> at ratio 10.6:1 64	
3.32 Infrared spectrum of Ni: en at ratio 10.6:1 63	
3.33 Infrared spectrum of Ni: BA at ratio 10.6:1 65	
3.34 Infrared spectrum of Ni-bentonite with deionized	
water 65	
3.35 Infrared spectrum of Co: NH <sub>3</sub> at ratio 13.1:1 66	
3.36 Infrared spectrum of Co: en at ratio 13.1:1 66	
3.37 Infrared spectrum of Co: BA at ratio 13.1:1 67	
3.38 Infrared spectrum of Co-bentonite with deionized	
water 67	
3.39 Electronic spectrum of Ni: NH <sub>3</sub> at ratio 10.6:1 68	
3.40 Electronic spectrum of Ni: en at ratio 10.6:1 68	
3.41 Electronic spectrum of Ni: BA at ratio 10.6:1 69	
3.42 Electronic spectrum of Ni-bentonite with deionized	
water 69	
3.43 Electronic spectrum of Co: NH <sub>3</sub> at ratio 13.1:1 70	
3.44 Electronic spectrum of Co: en at ratio 13.1:1 70	
3.45 Electronic spectrum of Co: BA at ratio 13.1:1 71	
3.46 Electronic spectrum of Co-bentonite with deionized	
water 71	
3.47 Diffuse reflectance spectrum of Ni: ligand at equal	
concentration 72	
3.48 Diffuse reflectance spectrum of Co: ligand at equal	
concentration 72 Years 172	
3.49 Infrared spectrum of Ni: NH <sub>3</sub> at ratio 1:3 83	
3.50 Infrared spectrum of Ni: NH <sub>3</sub> at ratio 5:1	
3.51 Infrared spectrum of Ni: NH <sub>3</sub> at ratio 50:1 84	
3.52 Infrared spectrum of Ni:BA at ratio 1:3 84	
3.53 Infrared spectrum of Ni:BA at ratio 5:1 85	

Figur	re	Page
3.54	Infrared spectrum of Ni: BA at ratio 50:1	85
	Infrared spectrum of Co: en at ratio 1:3	86
3.56	Infrared spectrum of Co: en at ratio 5:1	86
3.57	Infrared spectrum of Co: en at ratio 50:1	87
3.58	Infrared spectrum of Co: BA at ratio 5:1	87
3.59	Infrared spectrum of Co: BA at ratio 1:3	88
3.60	Infrared spectrum of Co: BA at ratio 50:1	88
3.61	Electronic spectrum of Ni: NH <sub>3</sub> at ratio 1:3	89
3.62	Electronic spectrum of Ni: NH <sub>3</sub> at ratio 5:1	89
3.63	Electronic spectrum of Ni: NH <sub>3</sub> at ratio 50:1	90
3.64	Electronic spectrum of Ni: BA at ratio 1:3	90
3.65	Electronic spectrum of Ni: BA at ratio 5:1	91
3.66	Electronic spectrum of Ni: BA at ratio 50:1	91
3.67	Electronic spectrum of Co: en at ratio 1:3	92 7 5
	Electronic spectrum of Co: en at ratio 5:1	92
	Electronic spectrum of Co: en at ratio 50:1	93
3.70	Electronic spectrum of Co: BA at ratio 1:3	93
	Electronic spectrum of Co: BA at ratio 5:1	94
	Electronic spectrum of Co: BA at ratio 50:1	94
3.73	Diffuse reflectance spectrum of Ni: NH <sub>3</sub> at various	
	ratio $S_1=1:3$ $S_2=5:1$ $S_3=50:1$	95
3.74	Diffuse reflectance spectrum of Ni: BA at various	
	ratio $S_1=1:3$ $S_2=5:1$ $S_3=50:1$	95
3.75	Diffuse reflectance spectrum of Co: en at various	
	ratio $S_1=1:3$ $S_2=5:1$ $S_3=50:1$	96
3.76	Diffuse reflectance spectrum of Co: BA at various	
3	ratio $S_1=1:3$ $S_2=5:1$ $S_3=50:1$	96
	Infrared spectrum of Ni: en -bentonite	97
	Electronic spectrum of Ni: en -bentonite	97
3.79	Diffuse reflectance of Ni: en-bentonite	98 iversity

#### **Abbreviations**

BA butanoic acid bipy 2,2'-bipyridyl **DMG** dimethylglyoxime ethylenediamine en **ABS** absorbance  $^{\circ}C$ celsius degree  $cm^{-1}$ wavenumber g gram h hour M molar millilitre mlnm nanometre part per million ppm G.R. guarantee regent A.R. analytical regent L.R. laboratory regent asymmetric streching  $v_{as}$ symmetric streching in-plane bending or deformation δ symetric deformation  $\delta_s$ weak W strong S medium m shoulder sh

# ลิขสิทธิ์มหาวิทยาลัยเชียงใหม Copyright<sup>©</sup> by Chiang Mai University All rights reserved