

**The Development of a Resin-in-pulp Process for
the Recovery of Nickel and Cobalt
from Laterite Leach Slurries**

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This thesis is presented as part of the requirement for a doctorate of philosophy in Extractive Metallurgy at Murdoch University. The work described in this thesis is my own research unless otherwise stated and was carried out under the supervision of Professor M. J. Nicol.

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Abstract

The processing of laterite ores for the recovery of nickel and cobalt has increased as the reserves of exploitable sulphide ores have become depleted. The pressure acid leach process (PAL) has become the preferred option for the treatment of laterite ores. Difficulties associated with the poor settling characteristics of the pulp in the counter current decantation (CCD) circuit after pressure leaching has resulted in as much as 10% of the soluble nickel and cobalt reporting to the tailings. The objective of this project is the development of an alternative processing step for the recovery of soluble nickel and cobalt from the PAL tailings using resin-in-pulp (RIP) technology.

Commercially available chelating resins with the iminodiacetate functional group have been studied for their suitability for the adsorption of nickel and other metal ions from PAL tailings pulp. The Amberlite IRC 748 resin was found to be superior despite its lower nominal loading capacity. The resin with the highest nominal capacity was observed to adsorb less nickel as a result of the adsorption of greater amounts of the impurity ions. The equilibrium loading for nickel on the preferred resin was found to be similar from the ammonium and protonated form of the resin although the kinetics of adsorption is greater when the resin is initially in the ammonium form.

A comprehensive study has been made of the equilibrium adsorption of several metal ions on the resin as a function of the equilibrium pH of the solution. A relatively simple model of the equilibrium adsorption which includes the effect of pH has been developed

and the results compared with the experimental data obtained in the $M^{2+}/Na^+/H^+$ system. The model which requires two equilibrium constants has been found to fairly well describe the experimental results.

A study of the kinetics of the loading of nickel and cobalt from both solutions and pulp has shown that the rate can be described in terms of a first-order approach to equilibrium. The kinetic and equilibrium parameters were used to simulate the performance of a multi-stage counter current resin-in-pulp operation. A semi-quantitative study of the elution of the adsorbed metal ions from the resin by dilute sulphuric acid solutions was also undertaken.

The technical feasibility of the RIP process for the recovery of nickel and cobalt from the PAL tailings has been successfully demonstrated in both laboratory and pilot-plant studies using a five-stage adsorption process. Important parameters such as the operating pH and the residence times of pulp and resin in each stage were identified through the batch test work coupled to the simulation procedure.

The optimum pH for adsorption was found to be in the range 4 to 5 as this pH is high enough to maximise the adsorption of nickel and cobalt while preventing precipitation of nickel and cobalt as hydroxides from the pulp. A method for minimizing the competition from more strongly loaded ions such as iron(II) and chromium(III) which are present in the pulp was also developed in the initial laboratory phase of the project and utilized during the pilot operation.

Problems associated with the preparation of the pulp preparation, elution of the loaded resin and control of the adsorption train were resolved during several pilot plant runs on site at a local PAL plant. These and other minor improvements and adjustments to the operating procedure culminated in a successful continuous run for several days during

which the target recovery of 90% for nickel and 60% for cobalt was exceeded throughout the run.

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Contents

Abstract	i
Acknowledgement	iv
Contents	v
List of Figures	x
List of Tables	xv
Nomenclature	xviii
Chapter 1 Introduction	1
1.1 Nickel	1
1.2 Cobalt	2
1.3 The Production of Nickel in Western Australia	3
1.4 Potential Nickel Developments	5
1.5 Geology and Mineralogy of Nickel Ores	7
1.5.1 Nickel Sulphide Ores	7
1.5.2 Nickel Laterite Ores	7
1.5.3 Characteristics of Australian Laterite Ores	9
1.6 Processes for the Treatment Nickel Ores	10
1.6.1 Sulphide versus Laterite Ores	10
1.6.2 Processing Options for Laterite Ores	11
1.6.2.1 Ferronickel Smelting	12

	1.6.2.2	Matte Smelting	14
	1.6.2.3	Reduction roast-Ammoniacal leach: The Caron Process	15
	1.6.2.4	Pressure Acid Leaching (PAL)	18
1.7		Recent Developments in Pressure Acid Leaching Technology (PAL)	21
1.8		Murrin Murrin, Bulong and Cawse Projects	25
	1.8.1	Murrin Murrin	25
	1.8.2	Bulong	27
	1.8.3	Cawse	27
1.9		Scope and Objective of This Projects	28
Chapter 2 Ion Exchange Technology for Nickel and Cobalt			30
2.1		Introduction	30
2.2		Development of Ion Exchange Resin	35
	2.2.1	Chelating Resins	36
	2.2.2	Synthesis of Chelating Resins	39
	2.2.3	General Structure and Properties of Chelating Resins	42
	2.2.4	Exchange Capacity	43
	2.2.5	Equilibrium Loading	45
	2.2.6	Equilibrium Adsorption Isotherms	46
	2.2.7	The Kinetics of Ion Exchange Processes	48
2.3		Ion Exchange Resins for the Adsorption of Nickel and Cobalt	55
	2.3.1	Iminodiacetic Acid (IDA) Chelating Resins	56
	2.3.2	Adsorption Behaviour of Nickel and Cobalt onto Iminodiacetic Acid Chelating Resins	60
2.4		Recovery of Nickel and Cobalt by Ion Exchange	61

Chapter 3	Materials and Methods	67
3.1	Reagents and Chemicals	67
3.2	Preparation and Characterisation of Resin Samples	69
3.2.1	Preconditioning	69
3.2.2	Particle-size Distribution	69
3.2.3	Density	70
3.2.4	Determination of Wet Volume Capacity by Acid-base Titration	71
3.2.5	Breakdown of Resin Beads	73
3.3	Analysis	76
3.3.1	Solution Assay	76
3.3.2	pH-Eh Measurement	76
3.3.3	Titration Analysis for Nickel	76
3.4	Equilibrium and Kinetic Studies	78
3.4.1	Procedure for Obtaining Equilibrium Isotherms	79
3.4.2	Kinetics of Loading	80
3.5	Loading of Nickel and Cobalt from Pulp	81
3.5.1	Laboratory Testwork	81
3.5.1.1	Preparation of the Pulp	81
3.5.1.2	Loading of Nickel and Cobalt	81
3.5.1.3	Equilibrium Isotherm of Nickel and Cobalt	82
3.5.1.4	Kinetics of Loading	82
3.5.1.5	Elution Profiles	83
3.5.2	RIP Miniplant Operation	84
3.5.2.1	Feed Preparation	84
3.5.2.2	Adsorption	84
3.5.2.3	Elution	88
3.5.3	Pilot Plant Operation	88

	3.5.3.1	Feed Preparation	88
	3.5.3.2	Adsorption	89
	3.5.3.3	Elution	95
Chapter 4		Results and Discussions	98
4.1		Preliminary Testwork	98
4.2		Oxidation and Neutralisation of the Pulp	102
4.3		Selection of the Chelating Resin	105
	4.3.1	Metal Loading Behaviour	106
	4.3.2	Kinetics of Adsorption	109
	4.3.3	Elution	114
	4.3.4	Preliminary Evaluation of Lewatit Mono Plus TP 207 Resin	116
4.4		Characterisation of the Iminodiacetic Chelating Resin	118
4.5		Equilibrium Adsorption Isotherm	120
	4.5.1	Equilibria Involving Metal Ions and Sodium Ions with the Resin	136
	4.5.2	Equilibria Involving Two Metal Ions and Sodium Ions with the Resin	144
4.6		Further Laboratory Pulp Testwork	148
	4.6.1	Equilibrium Isotherm of Nickel from CCD Pulp	148
	4.6.2	Loading in Several Stages	151
4.7		Simulation of an RIP Process	152
	4.7.1	The Model	153
	4.7.2	Adsorption Parameters	158
	4.7.3	Information Required for an RIP Plant	160
	4.7.4	SIMRIP Simulation for Nickel Recovery	161
4.8		RIP Miniplant Testwork	165
	4.8.1	Miniplant Run 1	161

4.8.2	Miniplant Run 2	172
4.9	RIP Pilot Plant Testwork	176
4.9.1	RIP Pilot Plant Run 1	177
4.9.1.1	Operation and Adsorption	178
4.9.1.2	Metals Recoveries and Mass Balances	181
4.9.1.3	Elution	183
4.9.2	RIP Pilot Plant Run 2	187
4.9.2.1	Operation and Adsorption	189
4.9.2.2	Metals Recoveries and Mass Balances	191
4.9.2.3	Elution	192
4.9.3	RIP Pilot Plant Run 3	193
4.9.3.1	Operation and Adsorption	195
4.9.3.2	Metals Recoveries and Mass Balances	197
4.9.3.3	Elution	199
Chapter 5	Conclusions and Recommendations	200
	References	205
	Appendix A	219
	Appendix B	223
	Appendix C	229
	Appendix D	231
	Appendix E	256
	Appendix F	258
	Appendix G is Provided on CD	

List of Figures

		Page
<i>Figure 1.1</i>	<i>Markets for nickel</i>	2
<i>Figure 1.2</i>	<i>Schematic flowsheet for ferronickel smelting</i>	13
<i>Figure 1.3</i>	<i>Simplified flowsheet of matte smelting (PT INCO, Indonesia)</i>	15
<i>Figure 1.4</i>	<i>Caron Process flowsheet (Monhemius, 1987)</i>	17
<i>Figure 1.5</i>	<i>The flowsheet of the original plant at Moa Bay, Cuba (Monhemius, 1994; Taylor, 1996)</i>	21
<i>Figure 1.6</i>	<i>Flowsheet of the AMAX acid leach process (Duyvesteyn et al., 1979; Monhemius, 1987)</i>	24
<i>Figure 2.1</i>	<i>The effect of pH on adsorption (Johns and Mehmet, 1985)</i>	32
<i>Figure 2.2</i>	<i>Vanadium profile across the RIP miniplant at steady state (Taylor et al., 2000)</i>	33
<i>Figure 2.3</i>	<i>Synthesis routes for ion exchange resins (Korkish, 1989)</i>	40
<i>Figure 2.4</i>	<i>Synthesis of iminodiacetic resin by attaching a chelating resin</i>	41
<i>Figure 2.5</i>	<i>Synthesis of iminodiacetic resin by nitration</i>	41
<i>Figure 2.6</i>	<i>Synthesis of iminodiacetic resin by nitration</i>	42
<i>Figure 2.7</i>	<i>Titration curves of representative resin types (Harland, 1994)</i>	44
<i>Figure 2.8</i>	<i>Equilibrium adsorption isotherm</i>	46
<i>Figure 2.9</i>	<i>Langmuir and Freundlich adsorption isotherm models ($K=54000$, $R_{max}=36.4$, $a=0.925$ and $b=0.0894$)</i>	48
<i>Figure 2.10</i>	<i>Schematic of rate determining steps in ion exchange (Harland, 1994)</i>	49
<i>Figure 2.11</i>	<i>Schematic representation of the shell progressive mechanism in a spherical ion exchange bead (Nativ et al., 1974)</i>	54
<i>Figure 2.12</i>	<i>Chemical structure of iminodiacetic acid</i>	57
<i>Figure 2.13</i>	<i>Chelate structure of iminodiacetic resin with divalent cation</i>	57
	<i>Titration curve of a typical iminodiacetic acid chelating resin (Diaz and</i>	

Figure 2.14	<i>Mijangos, 1987)</i>	59
Figure 2.15	<i>Protonations of the iminodiacetics species (Heitner-Wirguin and Ben-Zwi, 1970)</i>	59
Figure 2.16	<i>Capacity of XE 718 for copper (II), iron (III) and nickel (III) as a function of pH (Melling and West, 1984)</i>	61
Figure 2.17	<i>Effect of pH on nickel loading (Green et al., 1998)</i>	62
Figure 2.18	<i>Elution profile for iminodiacetic resin with 1 M sulphuric acid (Green et al., 1998)</i>	64
Figure 3.1	<i>Typical pH titration curve for iminodiacetic acid chelating resin</i>	72
Figure 3.2	<i>Photomicrograph of whole, chipped, cracked and broken resin beads</i>	74
Figure 3.3	<i>pH stat set up</i>	75
Figure 3.4	<i>Elution set up</i>	83
Figure 3.5	<i>Side elevation view of miniplant contactor</i>	85
Figure 3.6	<i>Plan view of miniplant contactor</i>	85
Figure 3.7	<i>Flowsheet depicting the RIP miniplant operation</i>	86
Figure 3.8	<i>Photograph of the miniplant RIP</i>	87
Figure 3.9	<i>Side elevation view of pilot plant contactor</i>	90
Figure 3.10	<i>Plant view of pilot plant contactor</i>	91
Figure 3.11	<i>Flowsheet depicting the recovery of nickel from CCD tails by a resin-in-pulp pilot plant</i>	92
Figure 3.12	<i>Photograph of the RIP pilot plant</i>	93
Figure 3.13	<i>Photograph of airlift and overflow screen</i>	93
Figure 3.14	<i>Photograph of rotameter and air header</i>	94
Figure 3.15	<i>Photograph of loaded resin vibrating screen</i>	94
Figure 3.16	<i>Side elevation view of elution column</i>	96
Figure 3.17	<i>Schematic diagram of elution set up</i>	97
Figure 3.18	<i>Photograph of elution column</i>	97
Figure 4.1	<i>Kinetics of loading of nickel onto resin (pH 4, resin volume 13.5 ml, agitator speed 200 rpm)</i>	100
Figure 4.2	<i>Kinetic of loading at pH 4 and 4.76 (resin volume 13.5 ml, agitator speed 200 rpm)</i>	101

Figure 4.3	<i>Kinetic fit for the loading of nickel onto various resins in the protons form</i>	112
Figure 4.4	<i>Kinetic fit for the loading of nickel onto various resins in the ammonia form</i>	112
Figure 4.5	<i>Kinetics of elution of nickel</i>	114
Figure 4.6	<i>Elution profile for nickel</i>	115
Figure 4.7	<i>Titration curve of the IRC 748 resin (87 ml in protons form) with 1.103 M sodium hydroxide solution at 25°C</i>	118
Figure 4.8	<i>(a) and (b) Derivative plot of the titration curve</i>	119
Figure 4.9	<i>Isotherms of nickel adsorbed onto resin at pH 3</i>	125
Figure 4.10	<i>Isotherms of nickel adsorbed onto resin at pH 4</i>	125
Figure 4.11	<i>Isotherms of nickel adsorbed onto resin at pH 5</i>	126
Figure 4.12	<i>Isotherms of cobalt adsorbed onto resin at pH 3</i>	126
Figure 4.13	<i>Isotherms of cobalt adsorbed onto resin at pH 4</i>	127
Figure 4.14	<i>Isotherms of cobalt adsorbed onto resin at pH 5</i>	127
Figure 4.15	<i>Isotherms of magnesium adsorbed onto resin at pH 3</i>	128
Figure 4.16	<i>Isotherms of magnesium adsorbed onto resin at pH 4</i>	128
Figure 4.17	<i>Isotherms of magnesium adsorbed onto resin at pH 5</i>	129
Figure 4.18	<i>Isotherms of manganese adsorbed onto resin at pH 3</i>	129
Figure 4.19	<i>Variation of K_R with pH</i>	131
Figure 4.20	<i>Plot of Log K as a function of pH</i>	133
Figure 4.21	<i>Protonations of the iminodiacetic species (Heitner-Wirguin and Ben-Zwi, 1970)</i>	133
Figure 4.22	<i>Actual and calculated NaOH added for nickel loading</i>	135
Figure 4.23	<i>Actual and calculated NaOH added for cobalt loading</i>	135
Figure 4.24	<i>Actual and calculated NaOH added for magnesium loading</i>	136
Figure 4.25	<i>Observed and calculated nickel loading at three pH tested</i>	140
Figure 4.26	<i>Observed and calculated cobalt loading</i>	140
Figure 4.27	<i>Observed and calculated magnesium loading</i>	141
Figure 4.28	<i>Sodium loading accompanying the loading of nickel</i>	142

<i>Figure 4.29</i>	<i>Sodium loading accompanying the loading of cobalt</i>	<i>143</i>
<i>Figure 4.30</i>	<i>Sodium loading accompanying the loading of magnesium</i>	<i>143</i>
<i>Figure 4.31</i>	<i>Nickel loading on the resin in the presence of cobalt</i>	<i>144</i>
<i>Figure 4.32</i>	<i>Nickel loading on the resin in the presence of magnesium</i>	<i>145</i>
<i>Figure 4.33</i>	<i>Loading isotherm of nickel in the pulp</i>	<i>150</i>
<i>Figure 4.34</i>	<i>Resin and pulp flow in countercurrent process</i>	<i>155</i>
<i>Figure 4.35</i>	<i>Kinetic plot</i>	<i>159</i>
<i>Figure 4.36</i>	<i>Equilibrium plot</i>	<i>160</i>
<i>Figure 4.37</i>	<i>Linear loading isotherm of nickel at low metal concentrations</i>	<i>163</i>
<i>Figure 4.38</i>	<i>Simulated profiles for solution and resin at steady state</i>	<i>165</i>
<i>Figure 4.39</i>	<i>Solution profiles after 5 and 10 hour of Run 1</i>	<i>167</i>
<i>Figure 4.40</i>	<i>Observed and predicted solution and loading profiles at steady state</i>	<i>169</i>
<i>Figure 4.41</i>	<i>Elution profiles for Run 1</i>	<i>170</i>
<i>Figure 4.42</i>	<i>Metal mass balance streams</i>	<i>170</i>
<i>Figure 4.43</i>	<i>Solution profiles after 5 and 10 hours of Run 2</i>	<i>173</i>
<i>Figure 4.44</i>	<i>Observed and predicted solution and loading profiles at steady state</i>	<i>173</i>
<i>Figure 4.45</i>	<i>Elution profiles for Run 2</i>	<i>175</i>
<i>Figure 4.46</i>	<i>Resin concentration and backmixing profiles</i>	<i>179</i>
<i>Figure 4.47</i>	<i>Loaded resin profile</i>	<i>180</i>
<i>Figure 4.48</i>	<i>Recovery of nickel and cobalt obtained during Pilot Run 1</i>	<i>182</i>
<i>Figure 4.49</i>	<i>Split elution</i>	<i>183</i>
<i>Figure 4.50</i>	<i>Elution profile for nickel</i>	<i>184</i>
<i>Figure 4.51</i>	<i>Typical elution profiles in Pilot Run 1</i>	<i>185</i>
<i>Figure 4.52</i>	<i>Photograph of the air regulator</i>	<i>188</i>
<i>Figure 4.53</i>	<i>Resin concentration and backmixing profiles</i>	<i>189</i>
<i>Figure 4.54</i>	<i>Loaded resin profile</i>	<i>190</i>
<i>Figure 4.55</i>	<i>Nickel and cobalt recovery profiles during Pilot Run 2</i>	<i>191</i>
<i>Figure 4.56</i>	<i>Elution profile for nickel in Run 2</i>	<i>193</i>

<i>Figure 4.57</i>	<i>Resin concentration and backmixing flowrate profiles in Run 3</i>	<i>195</i>
<i>Figure 4.58</i>	<i>pH profiles in each RIP adsorption tank</i>	<i>196</i>
<i>Figure 4.59</i>	<i>Nickel and cobalt recovery during the 3rd pilot run</i>	<i>198</i>

List of Tables

	Page	
<i>Table 1.1</i>	<i>Western Australian nickel mines</i>	4
<i>Table 1.2</i>	<i>Potential nickel developments in Australia</i>	6
<i>Table 1.3</i>	<i>Solubility products of metal hydroxides at 25°C (pK_{sp})</i>	8
<i>Table 1.4</i>	<i>Chemical composition of Australian laterites compared to Moa Bay laterite deposit (Kyle, 1996)</i>	10
<i>Table 2.1</i>	<i>Commercial chelating ion exchange resins (Eccles and Greenwood, 1992; Harju and Krook, 1995; Harland, 1994)</i>	38
<i>Table 2.2</i>	<i>Diffusion coefficients reported for particle diffusion in metal-iminodiacetic resins</i>	51
<i>Table 2.3</i>	<i>Selectivity orders of the iminodiacetic acid chelating resins compared to carboxylic and phosphonic acid resins</i>	56
<i>Table 2.4</i>	<i>Counter-current RIP extraction of metal cations from nickel liquor (Green et al., 1998)</i>	63
<i>Table 2.5</i>	<i>Precipitation of iron and copper during neutralisation (Duyvesteyn et al., 2001)</i>	65
<i>Table 3.1</i>	<i>Chemicals</i>	68
<i>Table 3.2</i>	<i>Chelating resins</i>	68
<i>Table 4.1</i>	<i>Feed and test results analysis</i>	99
<i>Table 4.2</i>	<i>Neutralisation of the feed pulp</i>	99
<i>Table 4.3</i>	<i>Composition of CCD pulp underflow solution phase</i>	102
<i>Table 4.4</i>	<i>Pulp properties</i>	102
<i>Table 4.5</i>	<i>Analysis of pulp during neutralisation and oxidation</i>	104
<i>Table 4.6</i>	<i>Physical and chemical properties of the resin studied</i>	106
<i>Table 4.7</i>	<i>Variation of the concentrations of metal ions in solution during loading</i>	108
<i>Table 4.8</i>	<i>Pseudo-equilibrium loading and kinetic parameters</i>	113

Table 4.9	<i>Pseudo-equilibrium loading and kinetic parameters of Mono Plus TP 207 compared to the conventional heterodisperse resin</i>	117
Table 4.10	<i>Comparison of the adsorption constants obtained for the Langmuir and Freundlich adsorption isotherms at different pH values</i>	124
Table 4.11	<i>Calculated values of the thermodynamic constant K_o assuming either 2 or 1 protons exchanged/metal ion</i>	132
Table 4.12	<i>Equilibrium constant of metal in $M^{2+}/H^+/Na^+$ equilibrium system</i>	139
Table 4.13	<i>Observed and calculated metal ions loading in the $M_1^{2+} / M_2^{2+} / H^+ / Na^+$ equilibrium system</i>	148
Table 4.14	<i>Adsorption constants obtained from the Langmuir and Freundlich adsorption isotherms for nickel in the pulp as compared to the solution</i>	150
Table 4.15	<i>Co-current RIP extraction of metal ions from CCD pulp</i>	151
Table 4.16	<i>SIMRIP Simulation for miniplant design and operation</i>	164
Table 4.17	<i>Predicted profiles</i>	166
Table 4.18	<i>Operating parameters for RIP miniplant</i>	166
Table 4.19	<i>Analysis of the solution phase in the feed pulp for Run 1</i>	166
Table 4.20	<i>Resin distribution in each tank after 10 hours.</i>	168
Table 4.21	<i>Resin loading profiles for Run 1</i>	168
Table 4.22	<i>Recoveries and mass balances in Run 1</i>	171
Table 4.23	<i>Resin loading profiles for Run 2</i>	174
Table 4.24	<i>Recoveries and mass balances in Run 2</i>	175
Table 4.25	<i>Main operating parameters for Pilot Run 1</i>	177
Table 4.26	<i>Feed preparation</i>	178
Table 4.27	<i>Average metals loading on the resin</i>	181
Table 4.28	<i>Recoveries and mass balances in Pilot Run 1</i>	182
Table 4.29	<i>Analysis of fresh and regenerated resin</i>	185
Table 4.30	<i>Metal ions concentration profile in the RIP adsorption tanks</i>	186
Table 4.31	<i>Effect of acidity on the composition of eluates from stripped resin</i>	187
Table 4.32	<i>Main operating parameters for pilot Run 2</i>	188
Table 4.33	<i>Average metals loading on the resin</i>	190

<i>Table 4.34</i>	<i>Recoveries and mass balances in Pilot Run 2</i>	<i>192</i>
<i>Table 4.35</i>	<i>Department of metal ion on the resin</i>	<i>193</i>
<i>Table 4.36</i>	<i>Operating parameters for Run 3</i>	<i>194</i>
<i>Table 4.37</i>	<i>Analysis of solids in the feed and tails</i>	<i>197</i>
<i>Table 4.38</i>	<i>Recoveries and mass balances in Pilot Run 3</i>	<i>199</i>

Nomenclature

<i>Symbol</i>	<i>Description</i>	<i>Unit</i>
a, b	<i>Freundlich constant</i>	
C_o	<i>Solution concentration at time 0</i>	<i>mol/l</i>
C_{EDTA}	<i>Concentration of EDTA</i>	<i>mol/l</i>
C_{NaOH}	<i>Concentration of NaOH</i>	<i>mol/l</i>
C_t	<i>Concentration of titrant</i>	<i>mol/l</i>
C_s^s	<i>Concentration of metal ion in solution at the resin bead surface</i>	<i>mol/l</i>
D	<i>Diffusion coefficient</i>	<i>cm²/s</i>
d	<i>Resin particle diameter</i>	<i>cm</i>
E	<i>Extraction of metal/stage</i>	<i>%</i>
K	<i>Equilibrium adsorption constant</i>	<i>l/mol</i>
k	<i>Rate constant</i>	<i>/hr</i>
k_r	<i>Mass transfer coefficient in resin</i>	<i>cm/s</i>
k_s	<i>Mass transfer coefficient in solution</i>	<i>cm/s</i>
K_1	<i>Metal equilibrium constant</i>	<i>mol/l</i>
K_{Na}	<i>Sodium equilibrium constant</i>	
K_0	<i>Thermodynamic constant</i>	
K_R	<i>Separation factor</i>	
L_r	<i>Resin flow-rate</i>	<i>l/hr</i>
L_s	<i>Solution flow-rate</i>	<i>l/hr</i>
M_r	<i>Mass of resin</i>	<i>g</i>
M_{ro}	<i>Mass of resin retained</i>	<i>g</i>

M_{rt}	<i>Mass of total resin seived</i>	<i>g</i>
N	<i>Number of RIP stages</i>	
Q_r	<i>Exchange capacity of a resin</i>	<i>eq/l</i>
r	<i>Radius of the resin bead</i>	<i>cm</i>
R_0	<i>Resin loading at time 0</i>	<i>mol/l</i>
R_e	<i>Resin loading at equilibrium</i>	<i>mol/l</i>
R_{max}	<i>Maximum resin loading</i>	<i>mol/l</i>
R_t	<i>Resin loading at time t</i>	<i>mol/l</i>
S	<i>Swelling ratio</i>	
SF	<i>Size fraction</i>	
t	<i>time</i>	<i>hr</i>
t_r	<i>Residence time of resin</i>	<i>hr</i>
V_{EDTA}	<i>Volume of EDTA</i>	<i>ml</i>
V_{NaOH}	<i>Volume of NaOH</i>	<i>ml</i>
V_r	<i>Volume of resin</i>	<i>ml</i>
V_{rH^+}	<i>Volume of resin in proton form</i>	<i>ml</i>
V_s	<i>Volume of solution sample</i>	<i>ml</i>
V_t	<i>Volume of titrant</i>	<i>ml</i>
WVC	<i>Wet volume capacity</i>	<i>eq/l</i>
y	<i>Number of protons</i>	
ρ_r	<i>Wet-settled density of a resin</i>	<i>g/ml</i>