

Optimization of Manganese Recovery from a Solution Based on Lithium-Ion Batteries by Solvent Extraction with D2EHPA

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Table S1. Conditions of the experimental design and concentrations of metals in the raffinate and in the organic phase after one extraction stage. Contact time of 10 min. Legend: [aq]: concentration of metal in aqueous phase, [org] concentration of meta in organic phase.

Standard Order	Random order	Coded variables			Real variables			Mn		Co		Ni		Li	
		pH	O:A	D2E HPA	pH	O:A	D2E HPA	[aq]	[org]	[aq]	[org]	[aq]	[org]	[aq]	[org]
1	6	-1	-1	-1	2.5	0.5	0.4	6.05	2.97	18.15	0.67	7.96	< 0.01	1.04	0.01
2	11	1	-1	-1	4	0.5	0.4	3.67	7.74	16.35	4.33	7.47	0.98	0.96	0.18
3	10	-1	1	-1	2.5	2	0.4	2.97	2.28	17.82	0.35	7.92	0.02	1.01	0.02
4	4	1	1	-1	4	2	0.4	0.63	3.45	14.34	2.09	7.96	< 0.01	1.04	< 0.01
5	14	-1	-1	1	2.5	0.5	0.6	5.31	4.45	17.75	1.53	7.84	0.25	1.00	0.10
6	5	1	-1	1	4	0.5	0.6	3.22	8.63	16.99	3.05	7.94	0.05	1.02	0.06
7	12	-1	1	1	2.5	2	0.6	1.55	3.00	18.35	0.33	7.96	< 0.01	1.02	0.02
8	13	1	1	1	4	2	0.6	0.24	3.65	10.37	4.07	6.75	0.61	0.94	0.06
9	18	0	0	0	3.25	1.25	0.5	2.09	4.28	17.73	0.44	7.96	< 0.01	1.05	< 0.01
10	8	0	0	0	3.25	1.25	0.5	2.03	4.33	17.50	0.79	7.92	0.04	1.02	0.02
11	7	0	0	0	3.25	1.25	0.5	2.04	4.32	17.52	0.78	7.93	0.02	1.02	0.03
12	9	0	0	0	3.25	1.25	0.5	2.28	4.13	17.69	0.65	7.96	< 0.01	1.02	0.02
13	15	-1	0	0	2.5	1.25	0.5	3.89	2.86	18.40	0.44	7.96	< 0.01	1.05	< 0.01
14	16	1	0	0	4	1.25	0.5	0.93	5.19	13.81	3.70	7.21	0.59	0.93	0.09
15	2	0	-1	0	3.25	0.5	0.5	4.66	5.76	16.85	3.33	7.48	0.97	0.97	0.16
16	1	0	1	0	3.25	2	0.5	0.70	3.42	15.49	1.51	7.37	0.30	0.96	0.04
17	17	0	0	-1	3.25	1.25	0.4	2.75	3.76	17.18	1.04	7.69	0.22	1.02	0.03
18	3	0	0	1	3.25	1.25	0.6	1.45	4.79	17.91	0.47	7.96	< 0.01	1.05	< 0.01

Table S2. Conditions of the experimental design, distribution ratios (D) and separation factors (β) after one extraction stage. Contact time of 10 min.

std order	random	Real variables			Distribution ratio (D)				log D				Separation factor (β)		
		pH	O:A	D2EHPA	D Mn	D Co	D Ni	D Li	log D Mn	log D Co	Log D Ni	Log D Li	Mn/C o	Mn/N i	Mn/Li
1	6	2.5	0.5	0.4	0.5	< 0.1	< 0.1	< 0.1	-0.3	-2.3	-3.3	-2.0	104	998	53
2	11	4	0.5	0.4	2.1	0.3	< 0.1	0.2	0.3	-0.6	-0.9	-0.7	8	16	11

3	10	2.5	2	0.4	0.8	< 0.1	< 0.1	< 0.1	-0.1	-1.7	-2.6	-1.7	39	272	43
4	4	4	2	0.4	5.5	0.1	< 0.1	< 0.1	0.7	-0.8	-3.9	-2.5	38	44750	1629
5	14	2.5	0.5	0.6	0.8	0.1	< 0.1	0.1	-0.1	-1.1	-1.5	-1.0	10	26	9
6	5	4	0.5	0.6	2.7	0.2	< 0.1	0.1	0.4	-0.7	-2.2	-1.2	15	425	46
7	12	2.5	2	0.6	1.9	< 0.1	< 0.1	< 0.1	0.3	-1.7	-3.9	-1.8	101	15798	125
8	13	4	2	0.6	15.4	0.4	0.1	0.1	1.2	-0.4	-1.0	-1.2	39	170	250
9	18	3.25	1.25	0.5	2.1	< 0.1	< 0.1	< 0.1	0.3	-1.6	-3.7	-	78	10646	-
10	8	3.25	1.25	0.5	2.1	< 0.1	< 0.1	< 0.1	0.3	-1.3	-2.3	-1.6	47	465	93
11	7	3.25	1.25	0.5	2.1	< 0.1	< 0.1	< 0.1	0.3	-1.4	-2.5	-1.6	48	733	85
12	9	3.25	1.25	0.5	1.8	< 0.1	< 0.1	< 0.1	0.3	-1.4	-3.7	-1.6	50	9373	77
13	15	2.5	1.25	0.5	0.7	< 0.1	< 0.1	< 0.1	-0.1	-3.4	-3.7	-	1652	3817	-
14	16	4	1.25	0.5	5.6	0.3	0.1	0.1	0.7	-0.6	-1.1	-1.0	21	68	58
15	2	3.25	0.5	0.5	1.2	0.2	0.1	0.2	0.1	-0.7	-0.9	-0.8	6	10	7
16	1	3.25	2	0.5	4.9	0.1	< 0.1	< 0.1	0.7	-1.0	-1.4	-1.3	50	122	110
17	17	3.25	1.25	0.4	1.4	0.1	< 0.1	< 0.1	0.1	-1.2	-1.6	-1.6	22	48	52
18	3	3.25	1.25	0.6	3.3	< 0.1	< 0.1	< 0.1	0.5	-1.6	-3.7	-2.5	125	17140	958

Table S3. Conditions of the experimental design and concentrations of metals remaining in the organic phase and in the stripping product. Legend: [aq]: concentration of metal in aqueous; phase, [org] concentration of metal in organic phase.

Rand om Order	St. order	Coded variables			Real variables			Mn		Co		Ni	Li	D ([aq]/[org])	
		[H ₂ S O ₄]	O:A	time	[H ₂ S O ₄]	O:A	time	[aq]	[org]	[aq]	[org]	[aq]	[aq]	D	MnD Co
9	1	-1	-1	-1	0.05	1	2	4	0.6	0.06	0.01	n.d.	< 0.01	6.3	5.4
14	2	1	-1	-1	2	1	2	4	0.8	0.05	0.01	n.d.	< 0.01	4.8	3.6
4	3	-1	1	-1	0.05	8	2	11	3.3	0.31	0.03	0.61	< 0.01	3.2	10.8
2	4	1	1	-1	2	8	2	19	2.3	0.26	0.04	0.29	< 0.01	8.1	7.5
15	5	-1	-1	1	0.05	1	25	5	< 0.1	0.08	< 0.01	n.d.	n.d.	-	-
11	6	1	-1	1	2	1	25	5	< 0.1	0.07	< 0.01	0.75	n.d.	-	-
3	7	-1	1	1	0.05	8	25	10	3.4	0.41	0.02	n.d.	< 0.01	3.1	23.3
8	8	1	1	1	2	8	25	28	1.1	0.42	0.02	0.25	< 0.01	24.6	26.5
16	9	0	0	0	1.025	4.5	13.5	17	0.8	0.26	0.01	n.d.	< 0.01	21.4	25.8
5	10	0	0	0	1.025	4.5	13.5	16	1.1	0.24	0.01	1.61	n.d.	15.5	18.1
7	11	0	0	0	1.025	4.5	13.5	16	1.1	0.24	0.01	n.d.	< 0.01	14.3	17.3
1	12	0	0	0	1.025	4.5	13.5	17	0.8	0.27	0.01	2.63	n.d.	21.4	38.4
18	13	-1	0	0	0.05	4.5	13.5	9	0.4	0.15	0.03	n.d.	n.d.	22.8	4.5
12	14	1	0	0	2	4.5	13.5	17	0.4	0.26	0.01	n.d.	< 0.01	44.1	27.5
10	15	0	-1	0	1.025	1	13.5	5	< 0.1	0.07	< 0.01	1.14	n.d.	-	-
6	16	0	1	0	1.025	8	13.5	23	0.4	0.36	0.02	0.41	< 0.01	64.4	15.7
13	17	0	0	-1	1.025	4.5	2	14	0.4	0.21	0.02	0.08	n.d.	35.0	9.6
17	18	0	0	1	1.025	4.5	25	22	< 0.1	0.34	< 0.01	n.d.	n.d.	-	-

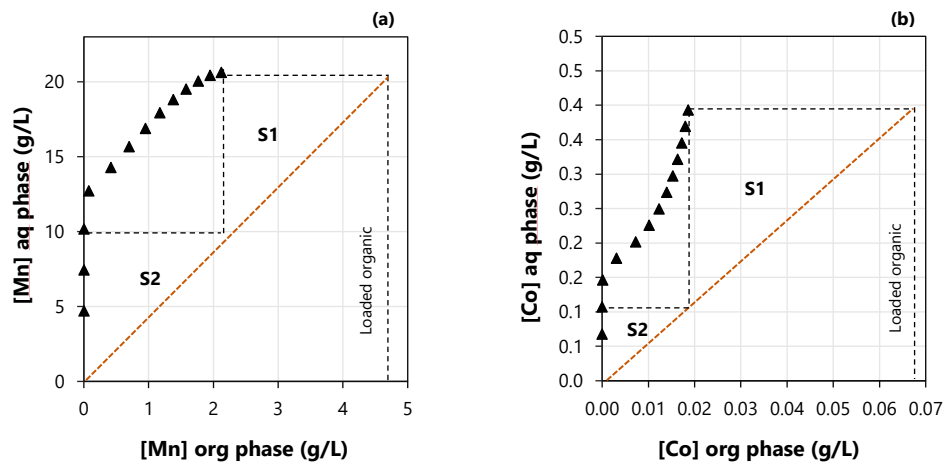


Figure S1. Distribution isotherms of (a) manganese stripping and (b) cobalt stripping obtained using the fitted models. Conditions used as input in the fitted models: stripping time: 13.5 min (coded variable: 0), O:A ratio: 8:1 (coded variable: +1), concentration of H_2SO_4 : 1 M (coded variable: 0).