

Electronic Supporting Information (ESI)

Efficient separation of rare earths recovered by a supported ionic liquid from bauxite residue leachate

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Table of contents

S1. EQUATIONS	2
Table S1 Separation factors between REEs and Sc(III) from equimolar solutions at $\text{pH}_{\text{eq}} \approx 2.6$ in the batch experiments.	2
Table S2 Separation factors between REEs at $\text{pH}_{\text{eq}} \approx 2.6$ in the batch mode.	2
Table S4 Summary of Sc(III) quantity and purity in fractions after purification by the SILP from a 10 mL of equimolar solution ($\text{pH}_{\text{ini}} = 1.5$).	4
Table S5 Summary of Nd(III) quantity and purity in fractions after purification by the SILP from 10 mL of equimolar solution ($\text{pH}_{\text{ini}} = 1.5$).	5
Table S6 Summary of Dy(III) and Y(III) quantity and purity in fractions after purification by the SILP from 10 mL of equimolar solution ($\text{pH}_{\text{ini}}=1.5$).	6
Table S7 Summary of REEs quantity and purity in fractions collected after purification by the SILP from 2 mL of real BR leachate.	7

S1. EQUATIONS

Space velocity, SV :

$$SV = \frac{Q}{BV} \quad (\text{eq S1})$$

where Q is the volumetric flow rate (mL h^{-1}) and BV is the bed volume (mL), regarded as the total volume of the SILP together with the void volume in the column.

Table S1 Separation factors between REEs and Sc(III) from equimolar solutions at $\text{pH}_{\text{eq}} \approx 2.6$ in the batch experiments.

	Y(III)/Sc(III)	Nd(III)/Sc(III)	Dy(III)/Sc(III)
Nitrate media	1.3	1.2	1.1
Sulfate media	4.2	3.4	3.6

Table S2 Separation factors between REEs at $\text{pH}_{\text{eq}} \approx 2.6$ in the batch mode.

	Y(III)/Nd(III)	Dy(III)/Nd(III)	Y(III)/Dy(III)
Nitrate media	1.1	1.3*	1.5
Sulfate media	1.2	1.1	1.2

*The value represents the Nd(III)/Dy(III) separation factor.

Table S3 Summary of bed volumes (BV) and adsorption capacities $q_{0.05}$ and q at breakthrough and exhaustive point, respectively: a) nitrate feed at 0.5 mL min^{-1} ($SV = 2.7 \text{ h}^{-1}$), b) nitrate feed at 2.0 mL min^{-1} ($SV = 10.8 \text{ h}^{-1}$) and c) sulfate feed at 0.5 mL min^{-1} ($SV = 2.7 \text{ h}^{-1}$).

	BV (mL) at $c/c_0 = 0.05$			BV (mL) at $c/c_0 = 1$			$q_{0.05}$ (mmol g^{-1})			q (mmol g^{-1})			$q_{0.05}/q$		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Ca(III)	4.64	5.57	4.64	5.57	6.04	5.11	0.047	0.057	0.042	0.051	0.062	0.045	0.918	0.919	0.921
Al(III)	5.11	5.57	5.57	6.04	6.96	7.43	0.035	0.046	0.042	0.038	0.050	0.050	0.929	0.923	0.841
Fe(III)	5.11	6.04	4.18	6.04	8.82	5.11	0.050	0.057	0.045	0.054	0.073	0.048	0.928	0.776	0.933
Sc(III)	5.57	6.04	3.71	6.50	8.36	4.18	0.045	0.052	0.029	0.050	0.064	0.029	0.892	0.821	1.000
Y(III)	6.04	6.04	5.57	8.36	9.29	11.1	0.059	0.066	0.057	0.070	0.084	0.065	0.846	0.779	0.888
Dy(III)	6.04	6.04	5.57	8.82	10.2	6.50	0.051	0.046	0.050	0.058	0.060	0.057	0.887	0.766	0.880
Nd(III)	6.50	6.50	5.57	11.6	12.1	11.1	0.058	0.058	0.044	0.081	0.085	0.054	0.711	0.686	0.811

$\text{pH}_{\text{ini}} = 1.5$, pH_{eq} ranges from 1.2 to 1.5. Adsorption capacities were calculated using eq 1.

Table S4 Summary of Sc(III) quantity and purity in fractions after purification by the SILP from a 10.0 mL of equimolar solution ($\text{pH}_{\text{ini}} = 1.5$).

Sc (mg)	Impurities (wt%)			V (mL) H_3PO_4	Ordinal number of fractions	BV
	Fe	Al	Ca			
Eluent: $\text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$						
0.065	0.00	0.00	0.00	25.0	3–7	1.39–3.25
0.353	15.3	0.00	0.00	5.00	8	3.71
0.020	95.3	0.00	0.00	15.0	9–11	4.18–5.11
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$						
0.072	0.00	0.00	0.00	30.0	3–8	1.39–3.71
0.377	13.1	0.00	0.00	5.00	9	4.18
0.018	96.2	0.00	0.00	20.0	10–11	4.64–5.11
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$						
0.062	6.46	0.00	0.00	25.0	3–7	1.39–3.25
0.377	17.5	0.00	0.00	5.00	8	3.71
0.017	96.0	0.00	0.00	15.0	9–11	4.18–5.11
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 2.0 \text{ mL min}^{-1} - \text{nitrate media}$						
0.138	0.00	0.00	0.00	30.0	2–6	0.93–2.79
0.061	0.00	0.00	0.00	5.00	7	3.25
0.303	61.5	0.00	0.00	15.0	8–11	3.71–5.11
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{sulfate media}$						
0.112	0.00	0.22	0.73	30.0	2–7	0.93–3.25
0.301	14.5	0.52	0.41	5.00	8	3.71
0.011	95.5	1.09	0.00	10.0	9–10	4.18–4.64

Other REEs were not detected in the Sc(III) fractions.

Table S5 Summary of Nd(III) quantity and purity in fractions after purification by the SILP from 10.0 mL of equimolar solution ($\text{pH}_{\text{ini}} = 1.5$).

Nd (mg)	Impurities (wt%)					V (mL) H_3PO_4	Ordinal number of fractions	BV
	Al	Ca	Dy	Fe	Y			
Eluent: $\text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$								
0.082	0.00	6.71	44.4	2.89	38.0	4.50	22	10.2
1.348	0.00	1.99	10.7	0.59	12.7	13.5	23–25	10.7–11.6
0.012	0.00	38.2	0.00	0.00	0.00	13.5	26–28	12.0–13.0
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$								
0.088	41.5	0.62	29.4	1.87	11.3	5.00	24	11.1
1.443	0.62	1.54	37.7	2.14	26.1	15.0	25–27	11.6–12.5
0.041	0.00	4.29	24.1	0.00	30.8	15.0	28–30	13.0–13.9
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{nitrate media}$								
0.525	0.00	2.18	48.5	3.21	29.6	18.0	28–31	13.0–14.4
0.738	0.00	0.72	5.37	0.37	6.81	4.50	32	14.9
0.177	0.00	1.99	1.84	0.16	1.73	22.5	33–37	15.3–17.2
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 2 \text{ mL min}^{-1} - \text{nitrate media}$								
0.500	0.75	1.41	48.5	3.01	30.5	27.0	26–31	12.1–14.4
0.709	0.00	1.60	34.2	2.31	29.9	4.50	32	14.7
0.472	0.00	7.96	10.2	0.21	9.86	31.5	33–39	15.3–18.1
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{sulfate media}$								
0.007	0.00	1.92	65.2	5.01	27.2	9.00	29–30	13.5–13.9
0.592	0.00	1.68	26.4	2.04	23.7	4.50	31	14.4
0.853	2.31	0.78	3.74	0.22	3.94	27.0	32–37	14.7–17.2

Sc(III) was not detected in the Nd(III) fractions.

Table S6 Summary of Dy(III) and Y(III) quantity and purity in fractions after purification by the SILP from 10.0 mL of equimolar solution ($\text{pH}_{\text{ini}}=1.5$).

Dy (mg)	Y (mg)	Impurities (wt%)				V (mL) H_3PO_4	Ordinal number of fractions	BV
		Al	Ca	Fe	Nd			
Eluent: $\text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1}$								
0.107	0.019	0.00	14.3	4.26	0.00	4.50	18	8.36
1.215	0.495	0.00	17.5	3.80	0.00	13.5	19–21	8.82–9.75
0.655	0.624	0.00	3.70	1.42	50.1	18.0	22–25	10.2–11.6
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - 0.5 \text{ mL min}^{-1}$								
0.168	0.065	41.5	0.62	1.87	15.4	5.00	24	11.1
1.701	1.178	0.62	1.54	2.14	32.0	15.0	25–27	11.6–12.5
0.024	0.031	0.00	4.29	0.00	40.8	15.0	28–30	13.0–13.9
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1}$								
0.020	0.003	26.9	2.30	10.8	0.00	4.50	26	12.1
1.431	0.663	0.00	2.14	4.27	1.18	18.0	27–30	12.5–13.9
0.393	0.406	0.00	1.45	1.14	62.1	18.0	31–34	14.4–15.8
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 2 \text{ mL min}^{-1}$								
0.019	0.005	78.2	0.00	0.22	0.00	4.50	25	11.6
1.086	0.576	1.28	1.27	3.49	4.55	22.5	26–30	12.1–13.9
0.722	0.666	0.00	2.82	1.44	51.0	27.0	31–36	14.4–16.7
Eluents: $\text{H}_3\text{PO}_4 - \text{HNO}_3 - \text{H}_3\text{PO}_4 - 0.5 \text{ mL min}^{-1} - \text{sulfate media}$								
0.020	0.000	89.4	0.00	0.00	0.00	4.50	25	11.6
1.167	0.399	0.72	1.63	5.23	0.40	22.5	26–30	12.1–13.9
0.374	0.341	0.99	1.29	1.26	64.5	31.5	31–37	14.4–17.2

Sc(III) was not detected in Dy(III) and Y(III) fractions.

Table S7 Summary of REEs quantity and purity in fractions collected after purification by the SILP from 2.0 mL of real BR leachate.

REEs	<i>m</i> (mg)	Impurities (wt%)									<i>V</i> (mL) H ₃ PO ₄	Ordinal nr. of fraction	<i>BV</i>
		Al	Ca	Dy	Fe	Nd	Sc	Si	Ti	Y			
Sc	0.007	4.25	63.8	0.00	24.0	0.00	0.27	1.18	6.48	0.00	30.0	1–6	0.46–2.79
Y	0.005	13.9	29.4	2.06	5.33	16.6	0.00	0.24	1.12	12.9	22.5	29–33	13.5–15.3
Dy	0.001												
Nd	0.010	23.6	36.9	1.66	6.90	19.7	0.00	0.20	0.90	10.2	22.5	31–35	14.4–16.2

Flow rate 0.5 mL min⁻¹, pH_{ini} = 1.2.