

# Efficient Extraction, Recovery, and Upgrading of Rare Earth Elements from Coal-Based Resources: Bioleaching and Precipitation

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**Table S1.** Comparison of Visual Minteq species calculations for leaching solutions with added magnesium carbonate for iron removal.

Species	Concentration	Activity	Log Activity	Fraction
Dy(CO <sub>3</sub> ) <sub>2</sub> <sup>−</sup>	$2.48 \times 10^{-26}$	$1.83 \times 10^{-26}$	−25.74	0.00%
Dy(SO <sub>4</sub> ) <sub>2</sub> <sup>−</sup>	$7.11 \times 10^{-06}$	$5.25 \times 10^{-06}$	−5.28	2.85%
Dy <sup>+3</sup>	$1.09 \times 10^{-04}$	$7.06 \times 10^{-06}$	−5.15	43.65%
DyCO <sub>3</sub> <sup>+</sup>	$6.20 \times 10^{-15}$	$4.57 \times 10^{-15}$	−14.34	0.00%
DyHCO <sub>3</sub> <sup>+2</sup>	$1.01 \times 10^{-11}$	$2.99 \times 10^{-12}$	−11.52	0.00%
DyOH <sup>+2</sup>	$1.74 \times 10^{-10}$	$5.14 \times 10^{-11}$	−10.29	0.00%
DySO <sub>4</sub> <sup>+</sup>	$1.34 \times 10^{-04}$	$9.87 \times 10^{-05}$	−4.01	53.51%
Eu(CO <sub>3</sub> ) <sub>2</sub> <sup>−</sup>	$1.12 \times 10^{-26}$	$8.23 \times 10^{-27}$	−26.08	0.00%
Eu(SO <sub>4</sub> ) <sub>2</sub> <sup>−</sup>	$2.43 \times 10^{-05}$	$1.79 \times 10^{-05}$	−4.75	9.73%
Eu <sup>+3</sup>	$9.37 \times 10^{-05}$	$6.06 \times 10^{-06}$	−5.22	37.49%
EuCO <sub>3</sub> <sup>+</sup>	$4.43 \times 10^{-15}$	$3.27 \times 10^{-15}$	−14.49	0.00%
EuHCO <sub>3</sub> <sup>+2</sup>	$8.11 \times 10^{-12}$	$2.40 \times 10^{-12}$	−11.62	0.00%
EuOH <sup>+2</sup>	$1.01 \times 10^{-10}$	$2.98 \times 10^{-11}$	−10.53	0.00%
EuSO <sub>4</sub> <sup>+</sup>	$1.32 \times 10^{-04}$	$9.73 \times 10^{-05}$	−4.01	52.78%
Fe(OH) <sub>2</sub> <sup>+</sup>	$6.04 \times 10^{-05}$	$4.46 \times 10^{-05}$	−4.35	0.17%
Fe(OH) <sub>3</sub> (aq)	$6.70 \times 10^{-12}$	$7.10 \times 10^{-12}$	−11.15	0.00%
Fe(OH) <sub>4</sub> <sup>−</sup>	$5.44 \times 10^{-17}$	$4.01 \times 10^{-17}$	−16.40	0.00%
Fe(SO <sub>4</sub> ) <sub>2</sub> <sup>−</sup>	$1.20 \times 10^{-03}$	$8.83 \times 10^{-04}$	−3.05	3.30%
Fe <sup>+3</sup>	$4.83 \times 10^{-03}$	$3.12 \times 10^{-04}$	−3.51	13.31%
Fe <sub>2</sub> (OH) <sub>2</sub> <sup>+4</sup>	$1.30 \times 10^{-03}$	$9.99 \times 10^{-06}$	−5.00	3.58%
Fe <sub>3</sub> (OH) <sub>4</sub> <sup>+5</sup>	$2.03 \times 10^{-04}$	$1.01 \times 10^{-07}$	−7.00	0.56%
FeOH <sup>+2</sup>	$2.85 \times 10^{-03}$	$8.45 \times 10^{-04}$	−3.07	7.86%
FeSO <sub>4</sub> <sup>+</sup>	$2.58 \times 10^{-02}$	$1.91 \times 10^{-02}$	−1.72	71.22%
Mg <sup>+2</sup>	$8.51 \times 10^{-02}$	$2.52 \times 10^{-02}$	−1.60	85.14%
Mg <sub>2</sub> CO <sub>3</sub> <sup>+2</sup>	$1.49 \times 10^{-16}$	$4.41 \times 10^{-17}$	−16.36	0.00%
MgCO <sub>3</sub> (aq)	$3.53 \times 10^{-16}$	$3.74 \times 10^{-16}$	−15.43	0.00%
MgHCO <sub>3</sub> <sup>+</sup>	$4.69 \times 10^{-10}$	$3.46 \times 10^{-10}$	−9.46	0.00%
MgOH <sup>+</sup>	$3.71 \times 10^{-11}$	$2.73 \times 10^{-11}$	−10.56	0.00%
MgSO <sub>4</sub> (aq)	$1.49 \times 10^{-02}$	$1.57 \times 10^{-02}$	−1.80	14.86%
Sc(OH) <sub>2</sub> <sup>+</sup>	$5.96 \times 10^{-11}$	$4.40 \times 10^{-11}$	−10.36	0.00%
Sc(OH) <sub>3</sub> (aq)	$4.71 \times 10^{-17}$	$4.99 \times 10^{-17}$	−16.30	0.00%
Sc(OH) <sub>4</sub> <sup>−</sup>	$2.43 \times 10^{-22}$	$1.79 \times 10^{-22}$	−21.75	0.00%
Sc(SO <sub>4</sub> ) <sub>2</sub> <sup>−</sup>	$1.72 \times 10^{-05}$	$1.27 \times 10^{-05}$	−4.90	6.89%
Sc <sup>+3</sup>	$4.19 \times 10^{-05}$	$2.71 \times 10^{-06}$	−5.57	16.75%
Sc <sub>2</sub> (OH) <sub>2</sub> <sup>+4</sup>	$7.77 \times 10^{-11}$	$5.97 \times 10^{-13}$	−12.22	0.00%
ScOH <sup>+2</sup>	$1.31 \times 10^{-07}$	$3.87 \times 10^{-08}$	−7.41	0.05%
ScSO <sub>4</sub> <sup>+</sup>	$1.91 \times 10^{-04}$	$1.41 \times 10^{-04}$	−3.85	76.30%
Y(CO <sub>3</sub> ) <sub>2</sub> <sup>−</sup>	$1.44 \times 10^{-26}$	$1.06 \times 10^{-26}$	−25.98	0.00%
Y(SO <sub>4</sub> ) <sub>2</sub> <sup>−</sup>	$1.98 \times 10^{-05}$	$1.46 \times 10^{-05}$	−4.84	7.90%
Y <sup>+3</sup>	$1.21 \times 10^{-04}$	$7.80 \times 10^{-06}$	−5.11	48.25%
Y <sub>2</sub> (OH) <sub>2</sub> <sup>+4</sup>	$4.06 \times 10^{-18}$	$3.12 \times 10^{-20}$	−19.51	0.00%
YCO <sub>3</sub> <sup>+</sup>	$5.70 \times 10^{-15}$	$4.20 \times 10^{-15}$	−14.38	0.00%
YHCO <sub>3</sub> <sup>+2</sup>	$7.39 \times 10^{-12}$	$2.19 \times 10^{-12}$	−11.66	0.00%
YOH <sup>+2</sup>	$1.18 \times 10^{-10}$	$3.50 \times 10^{-11}$	−10.46	0.00%
YSO <sub>4</sub> <sup>+</sup>	$1.10 \times 10^{-04}$	$8.09 \times 10^{-05}$	−4.09	43.85%