

Supplementary Information

Article

Towards Using MMO Anodes in Zinc Electrorefining: Mn Removal by Simulated Plant Off-Gas

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Table S1. Chronological description of the experiments.

Experimental steps	Experiment description	Goal of the experiment
1	Manganese removal without pH adjustment	To show the effect of pH on Mn removal reaction
2	Manganese removal with pH adjustment	
3	Effect of time: we performed several tests at various SO ₂ /air ratios in a prolonged test (80 min) to see how much Mn could be removed	To investigate the effect of time on Mn removal kinetics
4	Effect of cobalt on manganese removal: we performed several tests at SO ₂ /air ratios of 3%, 5%, and 6% with the presence of 10 mg/L Co as a catalyst	To show the catalytic effect of Co on Mn removal kinetics
5	Cobalt removal: we performed one test at a SO ₂ /air ratio of 6 % to examine Co removal without the presence of Mn in the zinc purification solution	To verify that Co cannot be removed without the presence of Mn in the zinc purification solution and precipitated MnO ₂ acts as a Co absorbent in this process
6	Effect of cobalt concentration on manganese removal: we performed several tests at a SO ₂ /air ratio of 6% with different Co concentrations ranging from 10 mg/L to 70 mg/L	To find the best Co concentration for optimizing Mn removal within the shortest time
7	Characterization of precipitates with SEM and EDS analyses: we conducted these two analyses on the precipitates which were collected after the Mn removal reaction under three different conditions: 1) without pH adjustment; 2) with pH adjustment; and 3) with pH adjustment and the presence of Co ions	To see their morphology and chemical composition
8	Characterization of precipitates with XPS analysis: we conducted XPS analysis on the precipitates collected at a SO ₂ /air ratio of 6% under two different conditions: 1) with the presence of Co and 2) without the presence of Co	To see the effect of Co on the chemical composition of precipitates and verify its presence in the precipitates
9	Characterization of the precipitates with XRF analysis	To have a better elemental analysis and more verification of the previous results

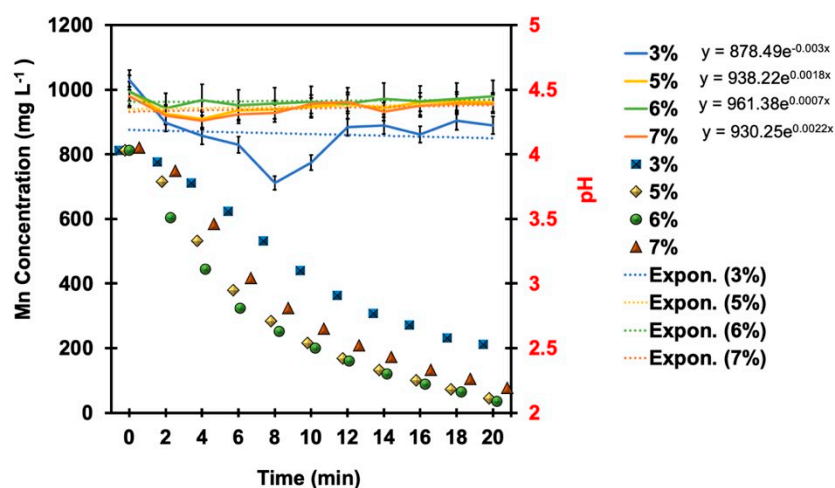


Figure S1. Manganese concentration (black colour) and pH (red colour) vs. time at different SO₂/air ratios under uncontrolled pH conditions (air flow rate = (500 ± 10) mL min⁻¹, SO₂ flow rate varied from 15 mL min⁻¹ to 35 mL min⁻¹, T = (80 ± 0.5) °C, agitation speed = 2000 rpm, initial [Mn] ≈ 1 g L⁻¹).

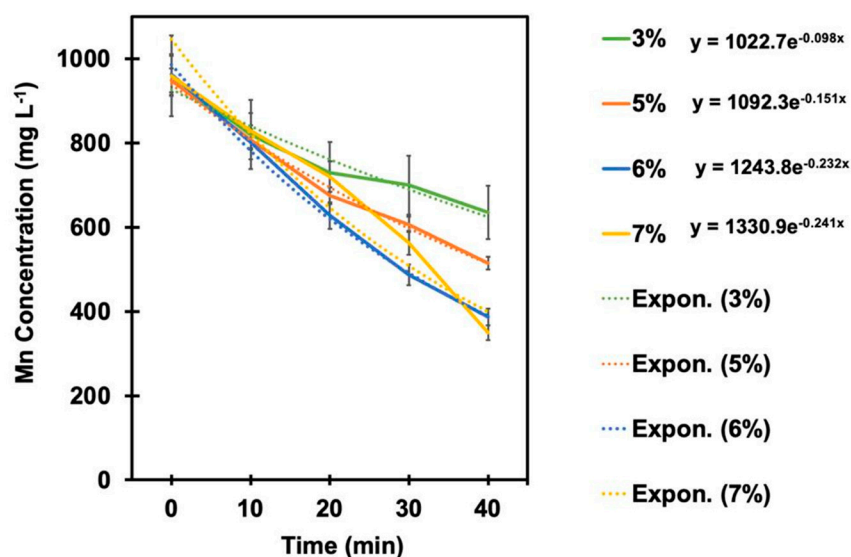


Figure S2. Manganese concentration vs. time at different SO₂/air ratios under pH-controlled conditions (air flow rate = (500 ± 10) mL min⁻¹, SO₂ flow rate varied from 15 mL min⁻¹ to 35 mL min⁻¹, T = (80 ± 0.5) °C, agitation speed = 2000 rpm, initial [Mn] ≈ 1 g L⁻¹).

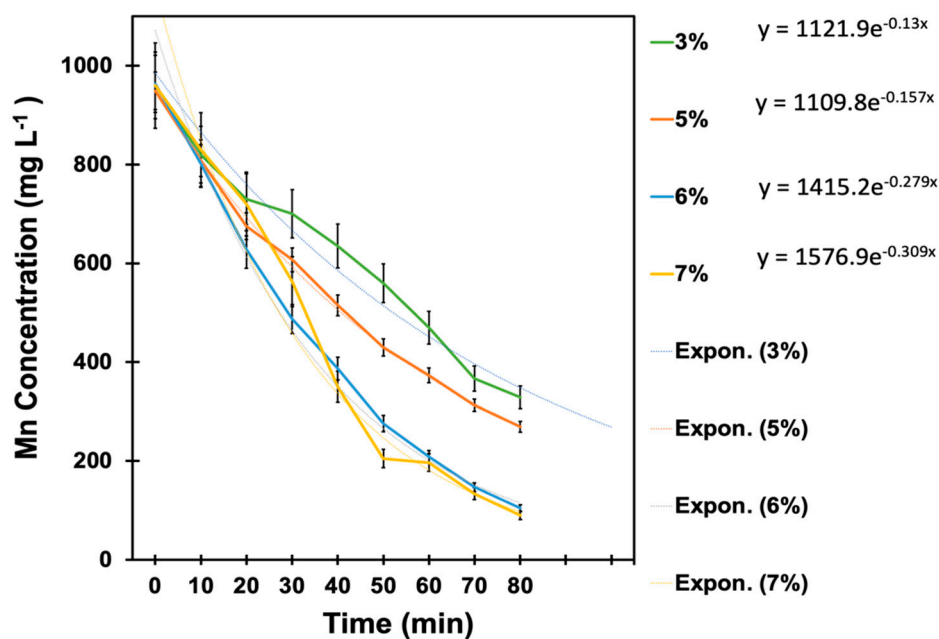


Figure S3. Manganese concentration vs. time at different SO₂/air ratios under pH-controlled conditions and prolonged tests without the presence of Co (air flow rate = (500 ± 10) mL min⁻¹, SO₂ flow rate varied from 15 mL min⁻¹ to 35 mL min⁻¹, T = (80 ± 0) °C, agitation speed = 2000 rpm, initial [Mn] ≈ 1 g L⁻¹).

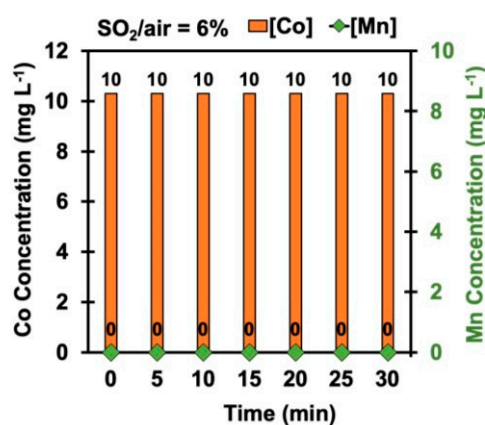


Figure S4. Cobalt concentration under pH-controlled conditions without manganese in the solution as a function of time at a SO₂/air ratio of 6%. The left y-axis is related to cobalt concentration (orange column) and the right y-axis is associated with manganese concentration (green diamonds), which was zero (air flow rate = (500 ± 10) mL min⁻¹, SO₂ flow rate = (30 ± 2) mL min⁻¹, T = (80 ± 0.5) °C, agitation speed = 2000 rpm, initial [Co] = 10 mg L⁻¹).

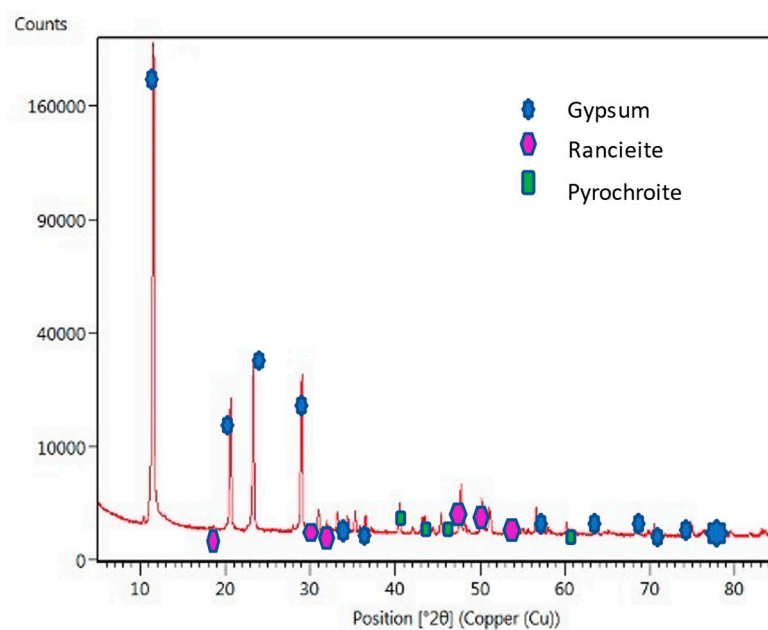


Figure S5. XRD diffraction patterns of precipitates obtained under pH-controlled conditions at a SO_2/air ratio of 6% without the presence of Co (air flow rate = $(500 \pm 10) \text{ mL min}^{-1}$, SO_2 flow rate = $(30 \pm 2) \text{ mL min}^{-1}$, $T = (80 \pm 0.5) ^\circ\text{C}$, agitation speed = 2000 rpm, initial $[\text{Mn}] = 1 \text{ g L}^{-1}$).