

Supplementary Materials: Separation and Recycling of Concentrated Heavy Metal Wastewater by Tube Membrane Distillation Integrated with Crystallization

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Table 1. Correspondence of saturation with the mass fraction of ZnSO₄ solution at 65 °C.

Saturation	Mass Fraction/%
0.34	20
1.0	42.64
1.1	44.98
1.2	47.14
1.3	49.14
1.38	50.63
1.4	51.00
1.5	52.72
1.6	54.32
1.7	55.82
1.8	57.23
1.9	58.55

Table 2. Correspondence of saturation with the mass fraction of NiSO₄ solution at 65 °C.

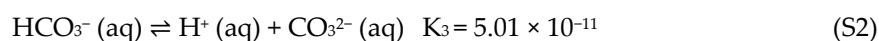
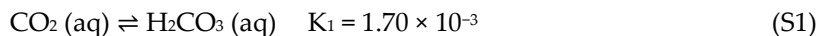
Saturation	Mass Fraction/%
0.43	20
1.0	36.64
1.1	38.88
1.2	40.97
1.3	42.92
1.38	44.39
1.4	44.74
1.5	46.45
1.6	48.06
1.7	49.57
1.8	51.00
1.9	52.35

1. Possibility Discussions of Carbonate and Hydroxide Salts during the Experiments

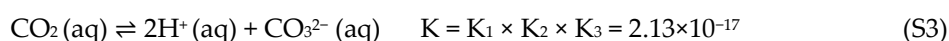
For hydroxide: $pK [Zn(OH)_2] = 3.3 \times 10^{-13}$; $pK [Ni(OH)_2] = 3.0 \times 10^{-16}$. In our experiments, the pH values are 4–5. So, the concentration of H⁺ is higher than 10^{-5} M and lower than 10^{-4} M. The concentration of OH⁻ is lower than 10^{-9} M.

In order to form the crystal of Zn(OH)₂, the concentration of Zn²⁺ should be higher than 3.3×10^5 M (2.16×10^7 g·L⁻¹). For the crystal of Ni(OH)₂, the concentration of Ni²⁺ should be higher than 3.0×10^2 M (1.76×10^4 g·L⁻¹). So, it is impossible to form the hydroxide precipitations in the experiments.

For carbonate: $pK [ZnCO_3] = 1.7 \times 10^{-11}$; $pK [NiCO_3] = 1.3 \times 10^{-7}$.



So,



The current, average concentration of CO₂ is 387 ppm, thus 1.32×10^{-5} M; the concentration of H⁺ is above 10^{-5} M. So, the concentration of CO₃²⁻ is below 1.61×10^{-15} M.

In order to form the crystal of ZnCO₃, the concentration of Zn²⁺ should be higher than 1.06×10^3 M (6.93×10^4 g·L⁻¹). For the crystal of NiCO₃, the concentration of Ni²⁺ should be higher than 8.07×10^7 M (4.74×10^9 g·L⁻¹).

So, it is impossible to form carbonate precipitations in the experiments.

Reference:

1. Fengcheng, S. *Basic environmental engineering chemical experiment, 2nd ed.*; Wunan Publishing: Taiwan, China, 2017; pp. 91–93.
2. Carbon Dioxide as an Acid. Available online: <http://butane.chem.uiuc.edu/pshapley/GenChem1/L25/1.html> (accessed on 13 01 2020).



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