

Lecture #13

Modeling of Hydro-Electrometallurgical Processes

Hydro-electrometallurgy involves the use of aqueous solutions to extract and recover metals via electrochemical processes. These processes are integral to industries producing high-purity metals and alloys. Modeling such processes provides insights into reaction kinetics, mass transport, and energy efficiency.

This lecture focuses on modeling hydro-electrometallurgical processes, with examples of copper electrochemical recovery and nickel electroextraction. Key modeling considerations include electrolyte composition, electrode surface reactions, and transport phenomena.

Copper Electrochemical Recovery

Copper recovery from industrial waste streams or leach solutions is a critical process for sustainable resource management. The electrochemical reactions occur at the cathode and anode, as shown below:

- Cathode reaction: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu(s)}$
- Anode reaction: $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$

Key equations for modeling copper recovery include:

1. Nernst Equation: Determines the equilibrium potential as a function of Cu^{2+} concentration.

$$E = E^0 - (RT/2F) \ln(C_{\text{Cu}^{2+}})$$

2. Butler-Volmer Equation: Models current density (i) based on overpotential (η):

$$i = i_0 [\exp(\alpha F \eta / RT) - \exp(-\beta F \eta / RT)]$$

Mass transport is modeled using Fick's law for diffusion and convective contributions in stirred systems:

$$\partial C / \partial t = D \nabla^2 C - (\mathbf{v} \cdot \nabla C)$$

Nickel Electroextraction

Nickel electroextraction involves recovering nickel from aqueous solutions, typically containing nickel sulfate (NiSO_4). The electrochemical reactions are:

- Cathode reaction: $\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni(s)}$
- Anode reaction: $\text{H}_2\text{O} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^-$

Key factors for modeling include:

1. Electrodeposition rate, modeled as:

$$m = (M_i / zF) \int i \, dt$$

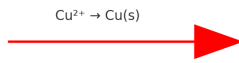
where m is the mass of deposited metal, M_i is the molar mass, z is the number of electrons, and F is Faraday's constant.

2. Mass transport, affected by diffusion and migration in the electrolyte.

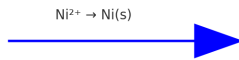
An additional consideration is the effect of impurities, which can alter electrode kinetics and deposition morphology.

Illustration: Hydro-Electrometallurgical Processes

Copper Recovery



Nickel Electroextraction



The schematic illustrates the electrochemical reactions involved in copper recovery and nickel electroextraction. These processes are characterized by electrode reactions and transport phenomena in the electrolyte.

Summary

Modeling hydro-electrometallurgical processes provides valuable insights into the reaction kinetics, mass transport, and energy efficiency of metal recovery systems. Copper electrochemical recovery focuses on reducing Cu^{2+} to Cu, while nickel electroextraction involves reducing Ni^{2+} to Ni. Understanding these processes is critical for optimizing industrial operations and improving sustainability.