

Influence of Magnetic Field on the Kinetics of Ho(III) Solvent Extraction Using D2EHPA

Konrad Wojtaszek^{1*}, Piotr Żabiński¹, Marek Wojnicki¹

¹AGH University of Krakow, al. Mickiewicza 30, 30-059 Krakow, Poland

*corresponding author: kwojtasz@agh.edu.pl

This study presents a comprehensive kinetic analysis of Ho(III) extraction using di-(2-ethylhexyl)phosphoric acid (D2EHPA) in the presence and absence of an external magnetic field. Aqueous solutions of Ho(III) chloride and organic D2EHPA solutions in Orlesol 110/170 were tested under varied experimental conditions, including pH, temperature, extractant concentration, and initial metal ion concentration. Spectrophotometric methods enabled determination of the reaction kinetics, with emphasis on distinguishing between diffusion and chemically controlled regimes.

In the absence of a magnetic field, the extraction process was found to follow reversible pseudo-first-order kinetics with a low activation energy ($E_a = -0.79 \text{ kJ mol}^{-1}$), indicating interfacial reaction control. However, application of a heterogeneous magnetic field (up to 0.42 T, Halbach configuration) significantly altered the kinetic profile. The activation energy increased to $167.7 \text{ kJ mol}^{-1}$, suggesting a mechanistic shift driven by magnetic field-induced changes in interfacial transport and complexation dynamics. Numerical simulations confirmed a radial magnetic field gradient within the cuvette, which could influence mass transport via magnetically induced convection.

The formation of a third phase at the aqueous-organic interface, identified as a flocculent Ho-D2EHPA-rich precipitate, was investigated using XRD, XRF, FTIR, XPS, and NMR. Its composition (approximate Ho:P = 3:2) and magnetic susceptibility imply its role as both a kinetic barrier and field interaction zone. Notably, NMR analysis showed substantial line broadening, confirming paramagnetic complexation and P-OH group participation in coordination.

This work demonstrates that magnetic fields can significantly influence REE solvent extraction, not only by accelerating kinetics but also by inducing new extraction pathways. These findings provide a foundation for magnetically assisted separation techniques and pave the way toward energy-efficient, selective rare-earth recovery systems.

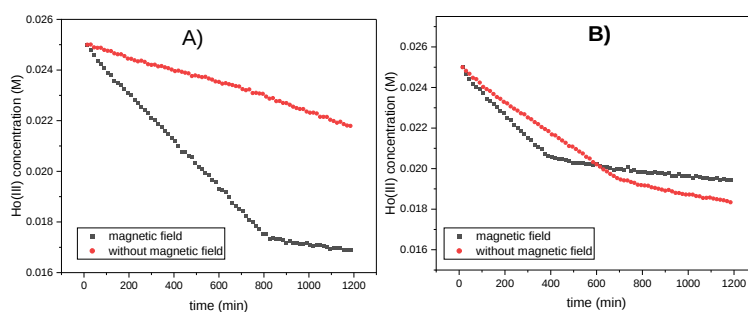


Figure 1. Comparison of the kinetic curves of the Ho(III) ion extraction process for temperatures of 30°C (A) and 35°C (B) in a field and without a magnetic field.