

# RECOVERY OF RARE EARTH ELEMENTS FROM NEODYMIUM MAGNET WASTE USING SIMULTANEOUS LEACHING AND PRECIPITATION WITH CARBOXYLIC ACIDS

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## Abstract

*This study provides the first insights into simultaneous leaching and precipitation of REEs from neodymium magnet waste using aqueous solutions of carboxylic acids. In preliminary experiments, seven commonly used carboxylic acids were screened for leaching of REEs from pretreated waste magnet material. The studied acids were found efficient in leaching of the magnet material during 24 hours. Formation of insoluble carboxylates of iron and neodymium was observed in some of the acids, indicating possibilities for separation of iron and neodymium according to solubilities of their carboxylates. Further studies with formic acid showed that by changing the concentration of the acid, iron and neodymium could be selectively precipitated during the leaching procedure.*

## Introduction

Rare earth elements (REEs) have become increasingly important in a variety of products and technologies, and recent uncertainties in their availability have made them one of the most critical raw materials. Neodymium magnets are one of the main uses of REEs, and as the most efficient permanent magnets currently available, neodymium magnets are widely used in e.g. large wind turbines, computer hard drives and cell phones. Several traditional methods for REE recovery from neodymium magnets exist, utilizing for example mineral acid leaching combined with oxalate or double-sulphate precipitation. However, due to the adverse environmental and human health impacts posed by the use of mineral acids, organic acids have recently been proposed as their replacements.<sup>1-3</sup> Common carboxylic acids used as diluted solutions are less hazardous than mineral acids, and have similar prices as well. Separation of REEs from iron is one of the most important aspects of REE recovery from neodymium magnets, for which selective leaching or precipitation has been proposed, as well as separation using solvent extraction. In

the specific case of carboxylic acid leaching, the formation of insoluble REE or iron carboxylates might give rise to selective leaching and precipitation of REEs.

## Experimental

Manually separated neodymium magnets originating from waste hard drive disks were used in the experiments. The magnets were first demagnetized in a muffle furnace at 400 °C for 4 h. The nickel coating was removed, and the material manually crushed to obtain smaller particle size. The material was then sieved for 10 min to obtain size fraction of <1 mm, which was used throughout the work.

A 0.25 g sample was dissolved in 12.5 ml of 1 mol/l carboxylic acid (acetic, ascorbic, citric, formic, glycolic, malonic, or tartaric acid) during 24 h in normal room temperature with stirring. The leaching experiments were done in triplicate. All samples were diluted 100-500-fold in 5 % nitric acid prior to analyses using ICP-OES. The precipitates formed during leaching were dissolved and analysed with ICP-OES for their elemental concentrations, as well as their structures using XRD.

## Results and discussion

The used carboxylic acids were found to leach the magnet material efficiently: only few magnet particles remained after 24 h of leaching. Precipitate formation was observed in all leaching solutions, except for acetic acid and citric acid. The only precipitate that could be identified with XRD analysis was neodymium formate in formic acid leachate. The spectra of other precipitates was interfered by iron, making interpretation difficult. The other precipitates were most likely respective REE/iron carboxylates of the used carboxylic acids. The precipitates formed in ascorbic and tartaric acids contained both iron and neodymium, as well as other REEs. Formic and malonic acid precipitates contained neodymium and other REEs, while glycolic acid precipitate contained only iron. The three latter carboxylic acids showed selectivity in precipitation for either REEs or iron, and could be used to separate REEs and iron from each other. Further studies with 0.1-1.0 mol/l formic acid indicated that by changing the concentration of the acid, iron and neodymium could be selectively precipitated during the leaching procedure.

## References

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