Höhere technische Bundeslehranstalt
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REECYPRO

Diplomarbeit

Schulautonomer Schwerpunkt
Bionik

ausgeführt im Schuljahr 2023/2024 von:

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January 2, 2024

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Abstract

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Introduction

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Contents

1 Introduction

Rare Earth Elements (REEs) play a critical role in modern-day life. They are used in nearly every device that uses electrical power to operate. A few examples where REEs are essential are: lasers, computer monitors, electric motors, electric generators, high-power magnets, liquid crystal displays (LCDs), solar panels and many more [6].

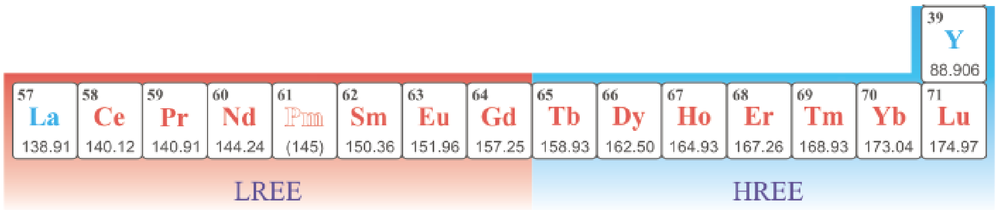

Figure 1.1: List of all rare earth elements. Those 16 elements can be further categorized into the light rare earth elements (LREEs) and the heavy rare earth elements (HREEs). Picture from lynasrareeaths.com.

1.1 Problem Setting^{TD}

Given the importance of REEs in the modern world, it is evident that the demand for them is increasing quickly. In the coming years, as the use of electronic devices increases, many of them will become electronic waste. It is vital for the world's future supply of rare earth elements to recycle them from this waste.

Currently used recycling methods for REEs are mostly damaging to the environment and very costly [4]. Therefore, only around one percent of the global REE usage is from recycled sources [5]. The rest comes from mining, which brings its own challenges. Rare earth ores (REOs) often contain radioactive elements which adds more complexity to the processing of the ores. Also, the extraction of REEs is done by using a process called flotation which produces large amounts of waste water. This waste water is highly problematic, as it often contains radioactive minerals, acids and toxic agents [7].

There are already thousands of tonnes of electronic waste that contain significant amounts of REEs. Recycling them would reduce the need of mining new REOs and therefore reduce the environmental impact of new electronic devices. Sadly, there is no easy and environmentally friendly process to recycle REEs on an industrial scale.

1.2 Contributions^{MS}

1.3 Structure of this Thesis^{MS}

2 System Overview

In order to understand the process of the recovery of rare earth elements from electronic waste with biosorption, the key procedures and techniques are described briefly in the following section.

2.1 Detection of REEs^{TD}

A relatively simple proof if a probe contains REEs is a precipitation reaction. It works by utilizing the +III and the +IV oxidization states of the REEs. These are used to form complexes with other molecules which express themselves as a coloured precipitation in the probe solution [1]. As an example, a Ce precipitation reaction is shown in 2.1 with an orange-red precipitate.

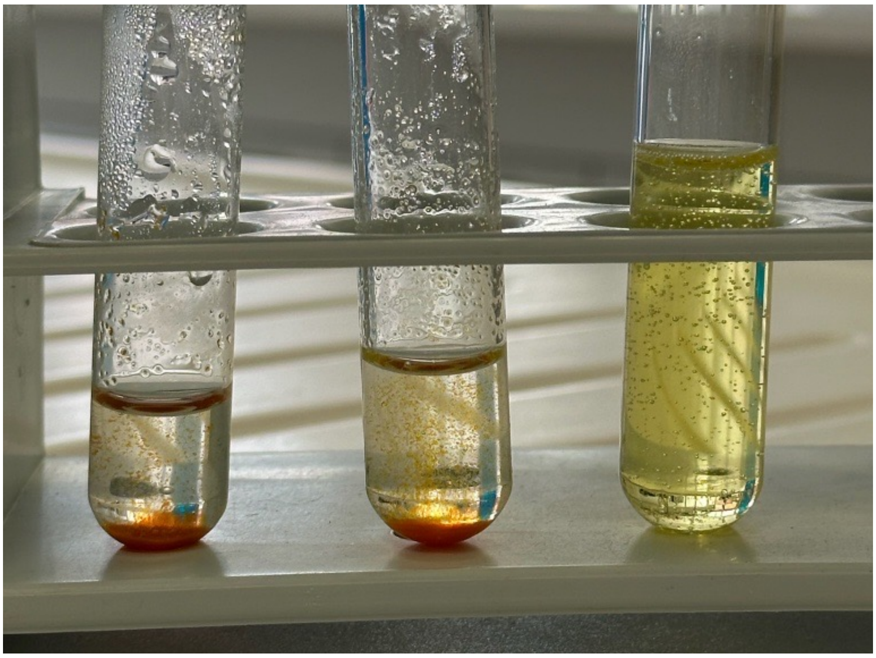

Figure 2.1: Precipitations of a successful REE detection reaction. The test tube on the righthandside does not show any precipitation because the probe was deionized water.

However, you must be careful, because of the REEs chemical similarity, the detection of a specific REE is not always possible with these precipitation methods.

[1] Jander/Blasius: "Lehrbuch der analytischen und präparativen anorganischen Chemie", Chapter 4.3.3.10

2.2 Bacteria^{MS}

2.2.1 Methylorubrum extorquens

2.2.2 Cultivation

2.3 Lanmodulin^{TD}

Lanmodulin (LanM) is a protein that is produced by *M. extorquens*, a lanthanide-utilizing bacteria [2]. LanM is not essential for the growth or survival of *M. extorquens*, and it is only produced when the bacteria are in a medium with presence of Ln^{III} or Ce^{III} ions [3]. However, the mechanisms that include LanM are not understood as a whole to this day.

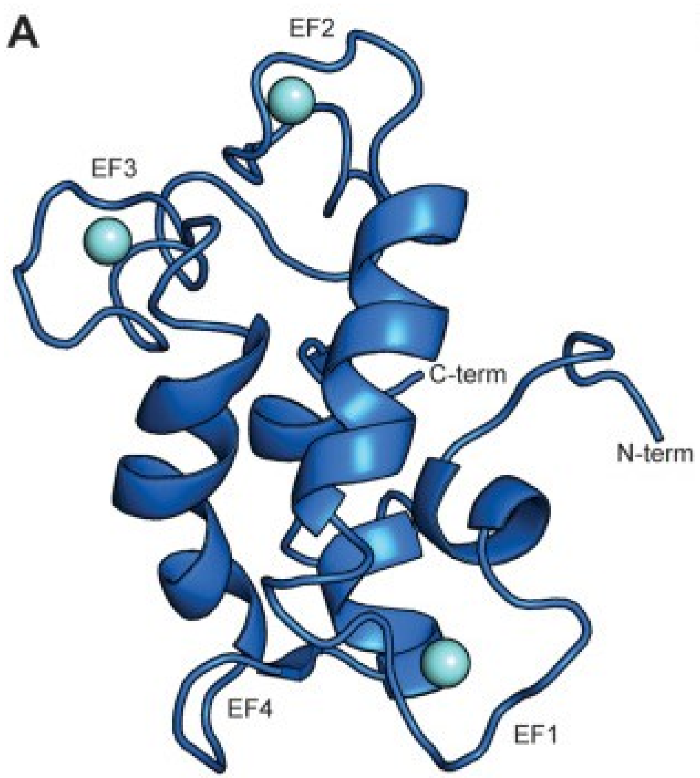

Figure 2.2: Graphical visualisation of the structure of lanmodulin. The EF-hands are indicated by EF, this is where the REEs can bind to the protein. In this visualisation the turquoise coloured spheres are Y^{III} ions which are bound to the EF-hands. Picture from "The biochemistry of lanthanide acquisition, trafficking and utilization", Emily R. Featherston and Joseph A. Cotruvo [3].

The most important characteristic of LanM is, that the molecule is able to bind lanthanide ions, primarily light REEs (LREEs). When LanM does this, it undergoes a transformation from a disordered state to a compact form of itself. The REEs are hereby bound to the so-called EF-hands which favour to bind to Ln^{III} and other lanthanoids over Ca^{II} which is usually associated with these EF-hands [1].

2.4 Protein Extraction[MS]

2.4.1 Cell Lysis

2.4.2 SDS-PAGE

2.5 IR-Spectrometry[MS]

3 Detection of REEs[MS]

Rare Earth Elements (for short: REEs) play a critical role in modern-day life. They are used in nearly every device that uses electrical power to operate. A few example where REEs are essential are: lasers, computer monitors, electric motors, high-power magnets, liquid crystal displays (LCDs), solar panels [6]. In this context, it is clear that the demand for REEs is rising rapidly. In the following years, with more and more electronic devices produced, most of them will eventually end as electronic waste. Recycling REEs from this waste is crucial for the worlds REE supply. Current recycling methods are mostly harmful to the environment and very costly [4]. But new recycling methods have emerged in the last years and one of them, using the technique of biosorption, is the subject of this thesis. To understand how this process works, it is important to know the following techniques.

3.1 Detail in A

3.1.1 Sub-Detail 1 in A

3.1.2 Sub-Detail 2 in A

3.2 Detail in A

4 Bacteria[MS]

5 Protein Extraction[TD]

6 IR-Spectrometry[TD]

7 Case Study

8 Evaluation^{MS}

9 Project Management[TD]

9.1 Planning

№	Milestone	Date of Achieval
MS_1	Cultivation of Bacteria	09.11.2023
MS_2	Extraction of LanM	07.12.2023
MS_3	Detection of LanM	n/d
MS_4	Binding of LanM to Rare Earth Elements	n/d
MS_5	Separation of Rare Earths from LanM	n/d

9.2 Evaluation

When we started to conduct some research for the project in the summer break, we also began simultaneously to plan the work with agile project management methods. As it turned out, doing the project management this way was really helpful. During our work, we encountered a lot of obstacles which we had not thought of before, which resulted in a slower progress than we had previously expected. Using an agile project board made it very easy for us to keep track of all of our work. Even though on some days we had to add more tasks to the *Todo* or *In Progress* than to the *Finished* section.

9.3 Timesheet

9.3.1 Tobias Daxecker

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9.3.2 Mathias Standhartinger

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Ort, Datum		*Unterschrift*

10 Future Work[MS]

11 Related Work[TD]

12 Conclusion

Acknowledgements

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Bibliography

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CV

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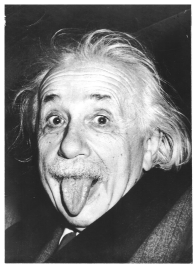

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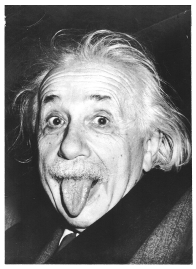

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