

REECYPRO

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Bionik

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February 21, 2024

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Abstract

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Introduction

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Contents

Abstract	iii
Introduction	iv
1 Introduction	2
1.1 Problem Setting ^{TD}	2
1.2 Contributions ^{MS}	2
1.3 Structure of this Thesis ^{MS}	2
2 System Overview	3
2.1 Detection of REEs ^{TD}	3
2.1.1 Precipitation Reactions	3
2.1.2 Arsenazo III Assay	4
2.2 Bacteria ^{MS}	4
2.2.1 Methylobacterium extorquens	4
2.2.2 Cultivation	4
2.2.3 Lanmodulin ^{TD}	4
2.3 Protein Extraction/IR-Spectrometry ^{MS}	5
2.3.1 Cell Lysis	5
2.3.2 SDS-PAGE	5
3 Detection of REEs^{TD}	6
3.1 Precipitation Reactions	6
3.1.1 Sub-Detail 1 in A	6
3.1.2 Sub-Detail 2 in A	6
3.2 Arsenazo III Assay	6
4 Bacteria^{MS}	7
5 Protein Extraction/IR-Spectrometry^{MS}	8
6 Case Study	9
7 Evaluation^{MS}	10
8 Project Management	11
8.1 Planning	11
8.2 Evaluation ^{TD}	11
8.3 Timesheet	12
8.3.1 Tobias Daxecker	12
8.3.2 Mathias Standhartinger	12

9 Future Work^{MS}	13
10 Related Work^{TD}	14
11 Conclusion	15
Acknowledgements	16
Listings	16
List of Figures	17
Bibliography	18
CV	20

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 [7].

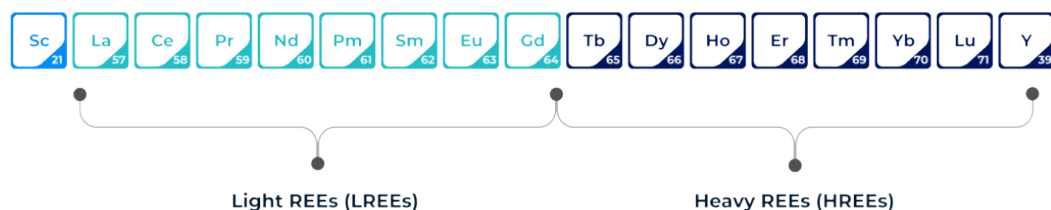


Figure 1.1: List of all rare earth elements. Those 17 elements (Scandium Sc is not listed) can be further categorized into the light rare earth elements (LREEs) and the heavy rare earth elements (HREEs). Picture from REIA / Argus Media.

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 [6]. 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 [8].

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}

2.1.1 Precipitation Reactions

A relatively simple proof if a probe contains REEs is a precipitation reaction. The precipitation reactions work because the rare earths form greater complexes with other molecules which have a different colour than the surrounding solution [9]. As an example, a Ce precipitation reaction is shown in 2.1 with an orange-red precipitate.

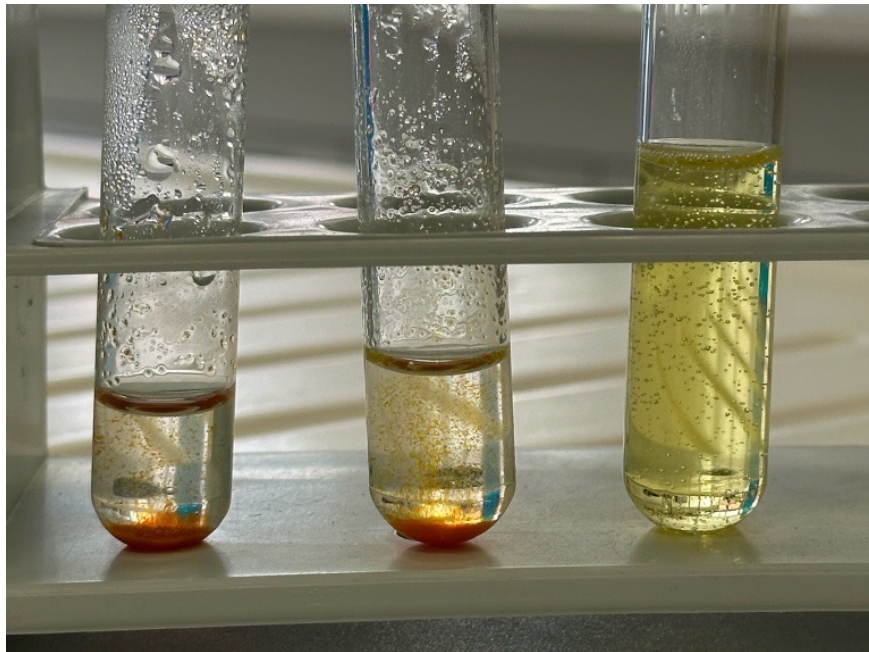


Figure 2.1: Precipitations of a successful REE detection reaction. The test tube on the righthandside does not show any precipitation because the probe was deionized water.

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. A precipitation reaction might also not be sensitive enough for your use case. So it could be possible that your probe contains rare earths, but you were not able to detect them.

2.1.2 Arsenazo III Assay

A better and more versatile method to detect rare earths in a probe is the so-called Arsenazo III Assay. With this assay, it is not only possible to detect if rare earths are present, but it is also possible to determine the concentration of REEs [5].

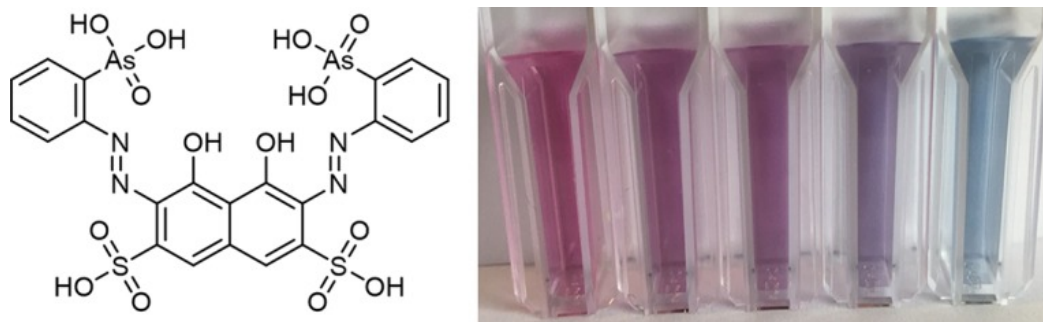


Figure 2.2: Structure of Arsenazo III. On the right you can see how the colour of the dye changes with the levels of REE concentration. Picture from "Facile Arsenazo III-based assay for monitoring rare earth element depletion from cultivation media for methanotrophic and methylotrophic bacteria" Hoogendorn et al. [5].

Arsenazo III is a metallochromic dye. This means that the dye changes its colour depending on the presence of metal ions (for example: 2.2). A second very important characteristic is that the colour of an Arsenazo III solution is also dependent on the concentration of some metal ions. The metal ions and the Arsenazo III molecule form complexes which block some certain frequencies of light. This property can be used to determine the concentration of rare earths in a probe.

2.2 Bacteria^{MS}

2.2.1 *Methyloburum extorquens*

2.2.2 Cultivation

2.2.3 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.

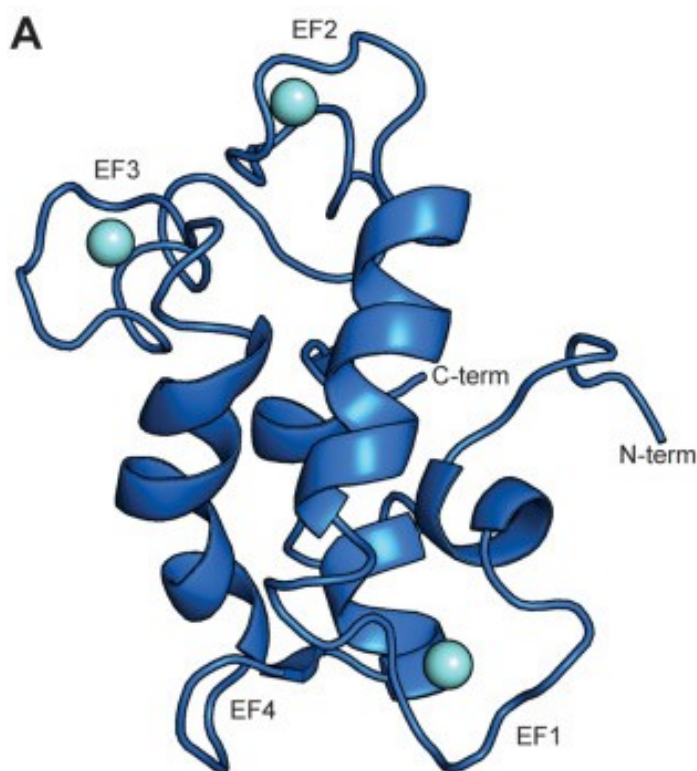


Figure 2.3: Graphical visualisation of the structure of lanmodulin. The EF-hands are indicated by EF, this is where the REEs can bind to the protein. In this visualisation the turquoise coloured spheres are Y^{III} ions which are bound to the EF-hands. Picture from "The biochemistry of lanthanide acquisition, 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].

2.3 Protein Extraction/IR-Spectrometry^{MS}

2.3.1 Cell Lysis

2.3.2 SDS-PAGE

3 Detection of REEs^{TD}

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 [7]. 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 Precipitation Reactions

3.1.1 Sub-Detail 1 in A

3.1.2 Sub-Detail 2 in A

3.2 Arsenazo III Assay

4 Bacteria^{MS}

5 Protein Extraction/IR-Spectrometry^{MS}

6 Case Study

7 Evaluation^{MS}

8 Project Management

8.1 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

8.2 Evaluation^{TD}

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.

8.3 Timesheet

8.3.1 Tobias Daxecker

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8.3.2 Mathias Standhartinger

Braunau/Inn, 21.02.2024

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9 Future Work^{MS}

10 Related Work^{TD}

11 Conclusion

Acknowledgements

Listings

List of Figures

1.1	List of all rare earth elements. Those 17 elements (Scandium Sc is not listed) can be further categorized into the light rare earth elements (LREEs) and the heavy rare earth elements (HREEs). Picture from REIA / Argus Media. . . .	2
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.	3
2.2	Structure of Arsenazo III. On the right you can see how the colour of the dye changes with the levels of REE concentration. Picture from "Facile Arsenazo III-based assay for monitoring rare earth element depletion from cultivation media for methanotrophic and methylotrophic bacteria" Hoogendorn et al. [5].	4
2.3	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].	5

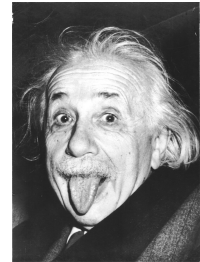
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