How low can we go?

Lowering detection limits of the rare earth elements in terrestrial and marine waters without pre-treatment using triple quadrupole ICP-MS analysis

Introduction

As a data science student getting the chance to be involved in research with in fields, physics and geology, that are quite new to me has been eye opening for the amount of impact I can have when I branch my skills into areas that I am interested in. Even when these interests seem like they may have nothing to do with my field, there are so many things we can learn from each other to work more effectively. Being brought onto a geology study where I get to work with emerging technology in the Astroparticle physics and the geology world and learn to analyze new data has helped me grow my skills so much. This advance in technology that I got to work with this summer is the triple quadrupole ICP-MS. The TQ-ICP-MS uses the combination of two analytical quadrupoles and a reaction cell. For our study we presented the approach for analyzing rare earth elements where we utilized the new iCap TQ from Thermo Fisher Scientific. The samples were from both ground and surface waters from the high Andes and marine waters from an estuary.

What are rare earth elements?

The rare earths are a group of 17 elements within the periodic table. This ranges from elements with atomic numbers 57 to 71 (Lanthanum to Lutetium), these are called the lanthanides, it also includes elements with the atomic numbers 21 and 39 (Scandium and Yttrium). Scandium and Yttrium differ from the lanthanides because their atomic structure, but they have similar chemical and physical properties. There is an abundance of these elements on the earth's crust, it also happens to follow a pattern from the periodic table. This pattern is that the lanthanides with even atomic numbers are more commonly found in nature than those with odd atomic numbers. Rare earths are important for many applications in the world today. Applications include things such as magnets, glass, luminescence, metal alloys and batteries[1]. They are also important in terms of understanding water-rock interactions, redox changes in ancient oceans and additions to ocean from deep sea hydrothermal systems.

Challenges with determining REEs

Determining and analyzing the Rare Earth Elements (REE) comes with challenges. For terrestrial waters they are typically found at low concentrations. These low concentrations can become challenging to impossible for methods used if they are out of range for most detection limits. In marine waters, there is the need to dilute the samples because of the salinity; these high salinities result in signal suppression in an ICP-MS plasma. In both terrestrial and marine waters the formation of oxides of the light REE and

Barium on the middle and heavy REE and, in particular, Europium poses a challenge when determining the REE.

Traditional methods have included preconcentration via chromatography [2], precipitation with hydroxides [3], evaporation [4], and analysis by quadrupole ICP-MS. Alternatively, many studies have relied on high resolution ICP-MS [1, 5]. The primary issue with HR-ICP-MS is that to achieve interference-free analyses of the MREE and HREE the increased resolution results in loss of sensitivity (higher detection limits), also slower for multi-element analysis.

Benefits and results of using TQ-ICP-MS

Unlike the currently popular HR-ICP-MS, the TQ-ICP-MS can reach detection limits low enough to be able to determine the rare earth elements for trace amounts at low concentrations without the need for any separation or preconcentration methods. HR-ICP-MS methods of require separation and/or preconcentration methods because the resolution of the machine takes away from its sensitivity. The sensitivity of the technology is necessary because it is key for determining REEs a low and especially ultralow amounts. The TQ-ICP-MS also has the ability to combine with cold plasma technology which can remove argon based inferences. Enabling this cold plasma allows the machine to run on a lower power and this suppresses the ionization of argon and carbon which removes polyatomic species that could have interfered with our target analyte ions.

How this can be applied to Astroparticle Physics

With the TQ-ICP-MS being proved effective for our study this equipment can also be used to benefit studies done in the field of Astroparticle physics. This can be a useful tool because ultra-trace detection limits also need to be pushed in the Astroparticle physics world. It will be especially helpful for ultra-trace detection of background contamination for this field.

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Sidney Leggett Wápiskisiw Pinésiw Iskwéw, she/her, August 2020

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Queen's UNIVERSITY

References

1. Bin Hu, M.B., Norbert Jakubowski, Jürgen Meinhardt, F. Michael Meyer, Jörg Niederstraßer, Rainer Schramm, Sven Sindern, Heinz-Günter Stosch, and Alfred Golloch, *Handbook of Rare Earth Elements: Analytics*, A. Golloch, Editor. 2017, De Grutyer, Inc. p. 402.
2. Carolina Hernández González, A.J.Q.C., Marta Fernández Díaz, *Preconcentration and determination of rare-earth elements in iron-rich water samples by extraction chromatography and plasma source mass spectrometry (ICP-MS).* Talanta, 2005. **68**: p. 6.
3. Hui-Fang Hsieh, Y.-H.C., Chu-Fang Wang, *A magnesium hydroxide preconcentration/matrix reduction method for the analysis of rare earth elements in water samples using laser ablation inductively coupled plasma mass spectrometry.* Talanta, 2011. **85**(2): p. 8.
4. Shaowei Wu, M.H., Bin Hu & Zucheng Jiang, *Determination of trace rare earth elements in natural water by electrothermal vaporization ICP-MS with pivaloyltrifluoroacetone as chemical modifier.* Microchimica Acta, 2007. **159**: p. 6.
5. Balaram, V., *Rare earth elements: A review of applications, occurrence, exploration, analysis, recycling, and environmental impact.* Geoscience Frontiers, 2019. **10**(4): p. 18.