



## X-RAY FLUORESCENCE

# Total Rare Earth Element Content in Mineral Ore and Concentrate

Lab Report 184

### Introduction

The demand for Rare Earth Elements (REE) has drastically increased due to their essential role in the global transition to renewable energy and advanced technologies. REE are used for special glass and ceramic products, permanent magnets, batteries, catalysts and more. REE containing catalysts are e.g., required for petrochemical refining and ammonia synthesis. NdFeB permanent magnets are used in consumer electronics, electric vehicles, wind turbines and more. Besides Nd these magnets can also contain small amounts of other REEs, like dysprosium (Dy), praseodymium (Pr), and terbium (Tb), which are added to enhance certain properties.

There are still large reserves of REE worldwide, but mining operations are cost-intensive

because the deposits are typically low-grade (< 1 wt.% total REE). Despite the growing demand, REE prices fluctuate, and mining operations are often working on the edge of profitability. To enable cost-efficient mining, X-ray Fluorescence (XRF) has become an indispensable tool along the entire process from exploration to blast hole analysis, mineral beneficiation and grade control. For complex ores with low concentrations like typical REE deposits, wave-length dispersive XRF (WDXRF) is often selected due to its higher spectral resolution and trace element sensitivity. However, especially during mineral beneficiation, energy dispersive systems (EDXRF) are great solutions to verify the total REE content during the concentration process.

In this lab report we demonstrate the performance of the S2 PUMA Series 2 EDXRF spectrometer for Yttrium (Y) analysis in REE ore. We highlight that elements like Yttrium and Cerium can be excellent indicator elements for the other REE elements, enabling a rapid monitoring during mineral beneficiation with the S2 PUMA.



## Rare Earth Elements and Indicator Elements

Rare earth elements (REE) are a group of 17 elements, including the 15 elements of the lanthanide series as well as the transition metals scandium (Sc) and yttrium (Y). REEs are often grouped into light and heavy REE based on their atomic number and physicochemical properties:

- Light REEs (LREE) : Sc, La, Ce, Pr, Nd, (Pm, instable isotope), Sm, Eu, Gd
- Heavy REEs (HREE): Y, Tb, Dy, Ho, Er, Tm, Yb, Lu

REEs are found in different geological formations. Primary deposits are carbonatites, and alkaline igneous rocks, which are formed by magmatic and hydrothermal processes. Secondary deposits are formed by weathering and erosion. Here, exploitable concentrations of REEs can be found in placer deposits, laterites, bauxite, clay deposits, sedimentary rocks and coal.

Studies have shown that it is possible to estimate the total REE amount in a given sample material from the concentration of an indicator element (Yang et al., 2020; Kruger, 2021). This approach works well if the samples are from the same ore deposit or geological formation and is thus suitable for mining operations. The indicator element is typically the most abundant one in the material. Considering the relative natural abundance this is usually La or Ce for light REEs or even all REEs and Y for heavy REEs.

## Optimal spectrometer configuration

The S2 PUMA Series 2, a versatile, high-performance benchtop EDXRF spectrometer, is an excellent solution for the mining industry. The optimized beam path, the 50-Watt power X-ray tube, and the HighSense™ Silicon Drift Detector (SDD) ensure short time-to-results in combination with outstanding analytical performance.

The XY-Autochanger (Figure 1) enables high sample throughput while remaining completely flexible: You can load mixed batches (liquids, powders, solids ...) and load, unload or prioritize new samples at any time. Bruker's unique SampleCare™ technology protects important system components, guaranteeing high instrument uptime and ensuring low cost of ownership even in dusty mining environments.



**Figure 1**  
S2 PUMA Series 2  
with XY-Autochanger

## Sample Preparation, Reference Materials & Calibration

The samples were ground, and 10 grams were loaded into plastic cups with a 4 µm Prolene® foil at the bottom. A set of 13 quartz monzonite reference materials with known concentrations for all 17 REE, including Y, was used to calibrate the S2 PUMA for Y analysis. The concentration ranges are summarized in Table 1. The measurement conditions were optimized to enable high precision and accuracy combined with short time-to-result (Table 2). Figure 2 and 3 show the calibration curve and peaks for Y KA, respectively.

**Table 1**

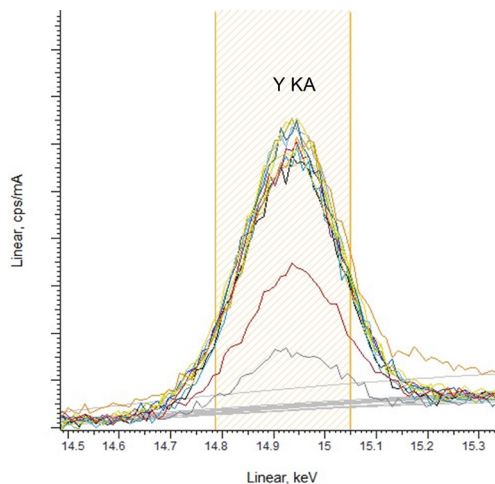
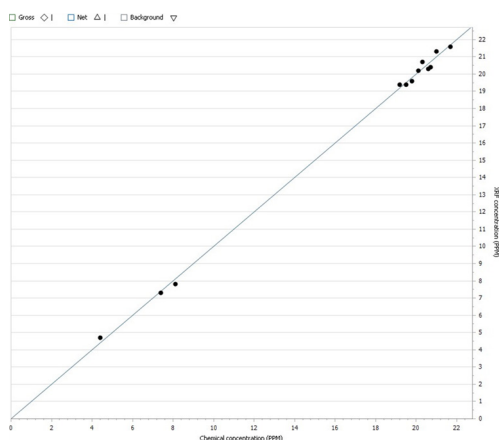
Concentration of range covered by the calibration (samples: quartz monzonite).

| Y (ppm)    | LREE (ppm)  | HREE (ppm) | Total REE (ppm) |
|------------|-------------|------------|-----------------|
| 4.4 – 21.7 | 15.6 – 40.8 | 6.8 – 32.6 | 22.4 – 70.7     |

**Table 2**

Measurement conditions.

| Elemental Line | Voltage | Current   | Filter      | Counting time | Sample Rotation | Mode |
|----------------|---------|-----------|-------------|---------------|-----------------|------|
| Y KA           | 50 kV   | Automatic | Cu (100 µm) | 300 s         | On              | Air  |



**Figure 2 (left)**

Calibration curve for Y KA line in quartz monzonite.  
 $R^2 = 0.9982$ ,  
 LLD = 0.2 ppm.

**Figure 3 (right)**

Peaks of the Y KA1 line in quartz monzonite.

## Analytical Performance

The analytical performance of the S2 PUMA for Y analysis was tested by measuring a reference material which was not part of the calibration multiple times. The sample was loaded and unloaded automatically by the XY-Autochanger between the measurements.

The results of the repeatability test are listed in Table 3, revealing an outstanding precision and accuracy. The lower limit of detection (LLD) is 0.2 ppm Y.

**Table 3**

Analytical repeatability and accuracy.

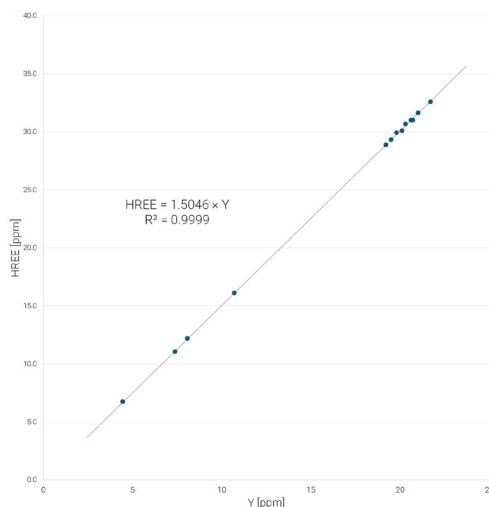
| Repetition           | Y (ppm)     |
|----------------------|-------------|
| #1                   | 16.4        |
| #2                   | 18.4        |
| #3                   | 15.1        |
| #4                   | 16.3        |
| #5                   | 17.7        |
| #6                   | 18.8        |
| #7                   | 17.9        |
| #8                   | 15.6        |
| #9                   | 15.7        |
| #10                  | 17.2        |
| <b>Average</b>       | <b>16.9</b> |
| <b>Abs Std. Dev.</b> | <b>1.3</b>  |
| <b>Certified</b>     | <b>16.7</b> |

## Determination of HREE content

Plotting Y concentrations measured by the S2 PUMA against the known total HREE contents of the quartz monzonite reference samples reveals a linear correlation (Figure 4), which can be described by:

$$\text{Total HREE} = 1.5046 \times Y; R^2 = 0.9999$$

Hence, based on the accurate Y contents provided by the S2 PUMA, the total HREE contents in this sample material type can be estimated rapidly and with a high certainty. Bruker's intuitive and powerful spectrometer software, SPECTRA.ELEMENTS, allows to define customized calculation modules to determine, display, and report the calculated total HREE content immediately.



**Figure 4**

Linear relationship between total HREE content and Y content in quartz monzonite samples.

## Conclusion

This lab report demonstrates the excellent analytical performance of the S2 PUMA Series 2 for the quantification of Y in geological samples. In agreement with previous studies (Yang et al., 2020; Kruger, 2021), a strong correlation was observed between the Y content and the total HREE content – in our case for quartz monzonite. Hence, for a given ore deposit or geological formation, indicator elements like Y, Ce, or La can be used to estimate the total REE (or HREE or LREE) content. This relationship allows to use the S2 PUMA for rapid production control analysis at mining sites. Ground ores or concentrates can be analyzed as powder within minutes to monitor the REE contents. SPECTRA.ELEMENTS allows to calculate and report the REE contents and even define production relevant thresholds enabling immediate decisions.

## References

**Yang, X., Kozar, D., Gorski, D. et al.** (2020) Using yttrium as an indicator to estimate total rare earth element concentration: a case study of anthracite-associated clays from northeastern Pennsylvania. *International Journal of Coal Science & Technology*, 7, p. 652–661

**Kruger, N.** (2021) Estimating Rare Earth Concentrations, *Geo News Newsletter*, North Dakota Department of Mineral Resources, 48(1), p. 5-7

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