

Application Note · PlasmaQuant 9x00 Series



Challenge

Sensitive analysis of trace elements and precise determination of major elements in digests of lithium ore samples

Solution

High-resolution ICP-OES with its DualView PLUS option provides an extended linear dynamic range from sub-ppb level to %-range

Intended audience

Mining companies or exploration firms that are interested in determining the lithium content of their ore samples for commercial purposes

Analysis of lithium ore with HR ICP-OES

Introduction

Lithium's economic significance is increasing as it plays a vital role in the creation of green energy storage devices like Li-ion batteries. As a result, the worldwide demand for lithium has risen, and in 2020, lithium was officially added to the list of critical raw materials published by the European Commission for the European Union. Brine deposits from salars or geothermal fields are the primary sources of lithium resources globally, but other essential sources include clays, granites, and granite-related pegmatites. Despite salar deposits containing the largest lithium reserve, lithium-rich mineral concentrates from pegmatites are presently the primary source of lithium production due to their higher grade and lower production costs^[1].

To access the lithium and convert it into industrial compounds, these minerals need to be processed. However, before processing, it's crucial to characterize the major and minor components of lithium-containing geological materials. While the lithium content is of most importance, the presence and concentration of other elements determine

the grade and processing procedure. Traditional exploration methods rely on identifying geological features that are indicative of mineral deposits. While these methods have been successful in identifying many mineral deposits, they are less effective for lithium deposits because lithium is more widely distributed in the earth's crust and is not associated with specific geological formations. Nowadays, lithium exploration includes the analysis for so called pathfinder elements, which are certain elements in the earth's crust being indicative of lithium deposits. These elements include, for example, beryllium, rubidium, cesium, and tantalum^[2,3]. Pathfinder elements provide a more effective exploration tool for lithium deposits because it is based on the distribution of elements that are chemically similar to lithium. This makes it possible to identify areas that are likely to contain lithium deposits even if they do not have the geological features typically associated with mineral deposits. Traditional exploration methods can be expensive and time-consuming, requiring extensive drilling and analysis. On the other hand, the pathfinder element

approach can be conducted more quickly and inexpensively by analyzing soil and rock samples.

Recently, Chinese standard methods summarized in the YS/T 509 series have been established for analyzing lithium ore. These standards mainly cover the different sample preparation procedures (fusion, multi-acid digestion on hot plate) for each targeted element (e.g., Be, Ca, Cs, Fe, Li, Rb, Mn) and recommends three different techniques for the analysis of the samples – flame atomic absorption, photometry, and complexation with ethylenediaminetetraacetic acid (EDTA). If one wants to determine all analytes according to these standards in the

lithium ore, this can become very time-consuming and is not very efficient.

The objective of this research is to simplify and speed up the overall analytical procedure for the analysis of major, trace, and pathfinder elements in lithium ore samples by exploring alternative sample preparations than mentioned in the YS/T 509 series and performing analyses with the PlasmaQuant 9200 ICP-OES. This approach takes advantage of the multi-element capability of an ICP-OES, reducing the complexity of the measurement process. Additionally, the speedwave XPERT microwave digestion system was employed, which reduces overall time and acid volumes needed for the sample preparation.

Materials and Methods

Sample preparation

All laboratory ware was previously washed with deionized (DI) water from a PURELAB system (18,2 MΩ cm, ELGA LabWater, High Wycombe, England). Chemicals were of analytical reagent grade. In order to verify the applicability and accuracy of the developed method, three certified reference materials (CRMs) were used: OREAS 750 (pegmatite lithium ore), OREAS 753 (pegmatite lithium ore), OREAS 999 (spodumene concentrate). Samples were prepared in two independent replicates per digestion procedure.

Procedure A (without HF complexation): Approximately 0.1 g of each duplicate were accurately weighed (0.0001 mg) into a digestion vessel (DAK100). Afterwards, 4 (± 0.1) mL conc. H₂SO₄, 2 (± 0.1) mL conc. HF, 1 (± 0.1) mL conc. HCl, and 2 (± 0.1) mL conc. HNO₃ were added. The mixture was swirled carefully and left standing for at least 15 minutes before the vessel was closed. Subsequent heating was performed stepwise (210 °C for 10 min (ramping 5 min), 230 °C for 10 min (ramping 2 min), 240 °C for 30 min (ramping 2 min)) in a speedwave XPERT microwave digestion system. Afterwards the vessels were allowed to cool to room temperature (RT) to avoid foaming and splashing. The solutions were transferred to a graduated polypropylene tube, diluted to 50 mL with DI water, and centrifuged (1125xg, 5 min). The resulting clear solutions of the two independent replicates were used for direct analysis. Procedure B (with HF complexation): After the first digestion step and cooling, the vessels were opened, 10 mL of a saturated H₃BO₃ solution were added, and the complexation of free HF was carried out at 180 °C (10 min, ramping

5 min). Afterwards the vessels were allowed to cool down again to RT, solutions were transferred to a graduated polypropylene tube, diluted to 50 mL with DI water, and centrifuged (1125 xg, 5 min). The supernatants of the duplicates were used for direct analysis.

Long-term stability was investigated by analyzing quality control (QC) standard solutions after each batch of 10 samples. Samples measured in between consisted of a solution mimicking a lithium ore sample. This solution was prepared in 1% (v/v) HNO₃ from single element standard solutions and contained the following analyte concentrations: 5 mg/L (P), 20 mg/L (Ca), 25 mg/L (Fe, K, Li), 50 mg/L (Mg, Mn, Na, Si), 150 mg/L (Al).

Calibration

All quantitative measurements were carried out against external calibration curves. Calibration levels for each element were chosen based on expected concentration range. At least three calibration standards were used for each element, as described in Table 1. Selected calibration curves are shown in Figure 1.

The multi-element stock solutions were prepared using single and multi-element standard solutions (Merck, Sigma-Aldrich), and through serial volume/volume dilution in polypropylene tubes. Blank solution, calibration and QC standards (see Table 1) were prepared in 1% (v/v) HNO₃. QC standards were obtained from a different multi-element stock solution than the source used for calibration standards.

Table 1: Concentration (mg/L) of calibration and quality control (QC) standards

| Element | As, Ba, Be, Bi, Co, Cr, Cs, Ga, Nb, Ni, Rb, Sb, Sn, Sr, Ta, Ti, Tl, V, W | Al | Ca, Fe, K, Li, Mn | Mg, Na | P |
|-----------|--|-----|-------------------|--------|------|
| Blank | 0 | 0 | 0 | 0 | - |
| Std. 1 | 0.01 | - | - | - | - |
| Std. 2 | 0.10 | - | - | - | - |
| Std. 3 | 1.0 | - | - | - | - |
| Std. 4 | - | - | 2.5 | 2.5 | - |
| Std. 5 | - | - | 10 | 10 | - |
| Std. 6 | - | 50 | 25 | 25 | - |
| Std. 7 | - | 100 | 50 | 50 | - |
| Std. 8 | - | 200 | - | 100 | - |
| Std. 9 | - | - | - | - | 1.0 |
| Std. 10 | - | - | - | - | 2.5 |
| Std. 11 | - | - | - | - | 5.0 |
| QC Std. 1 | 0.25 | - | - | - | 0.25 |
| QC Std. 2 | - | 50 | 25 | 25 | - |

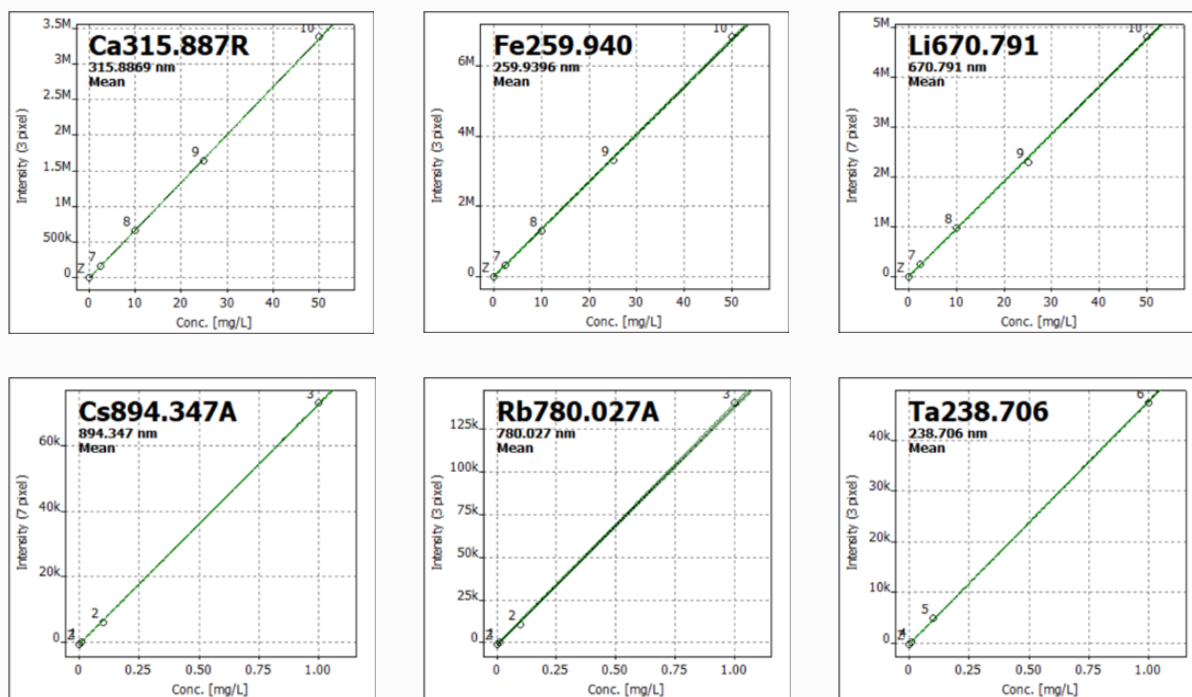


Figure 1: Selected calibration curves

Instrument settings

The analysis was performed on a PlasmaQuant 9100 Elite ICP-OES. Representative test measurements on a PlasmaQuant 9200 Elite confirmed consistent performance under the adjusted plasma conditions. The sample introduction components were selected to achieve a high level of sensitivity for trace elements in high matrix samples while being resistant to hydrofluoric acid. Axial, radial, and radial PLUS plasma viewing mode were selected, thus assuring best performance for traces and minerals. Teledyne CETAC ASX-560 Autosampler was coupled to the instrument. Individual settings and components are summarized in Table 2.

Table 2: Instrument settings

| Parameter | Specifications 9100 | Specifications 9200 |
|----------------------------|--|---------------------|
| RF power | 1250 W | |
| Plasma gas flow | 13 L/min | 9 L/min |
| Auxiliary gas flow | 0.5L/min | |
| Nebulizer gas flow | 0.6 L/min | |
| Nebulizer | Parallel path nebulizer, 1.0 mL/min, PFA | |
| Spray chamber | Cyclonic spray chamber, 50 mL, PTFE | |
| Outer tube/inner tube | Syalon/alumina | |
| Injector | Alumina, ID: 2 mm | |
| Pump tubing | PVC (black, black) | |
| Sample pump rate | 1.0 mL/min | |
| Fast pump rate | 5.0 mL/min | |
| Measuring delay/rinse time | 60 s/30 s | |
| Torch position | 0 mm | |

Method and evaluation parameters

Table 3: Method parameters

| Element | Line [nm] | Plasma view | Integration mode | Read Time [s] | Evaluation | | | |
|---------|-----------|--------------------------|------------------|---------------|---------------|------------------|---------------|------------|
| | | | | | No. of pixels | Baseline fit | Polyn. degree | Correction |
| Al | 396.152 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| As | 188.979 | axial | peak | 5 | 3 | ABC ¹ | auto | - |
| Be | 313.042 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Bi | 223.061 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Ca | 315.887 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Co | 228.615 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Cr | 267.716 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Cs | 894.347 | axial | peak | 3 | 7 | static | auto | - |
| Fe | 259.940 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Ga | 294.364 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| K | 766.491 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Li | 670.791 | radial PLUS ² | peak | 1 | 7 | ABC ¹ | auto | - |
| Mg | 285.213 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Mn | 293.931 | radial PLUS ² | peak | 1 | 3 | ABC ¹ | auto | - |
| Na | 589.592 | radial | peak | 1 | 3 | ABC ¹ | auto | - |

Table 3 (continued): Method parameters

| Element | Line [nm] | Plasma view | Integration mode | Read Time [s] | Evaluation | | | |
|---------|-----------|-------------|------------------|---------------|---------------|------------------|---------------|------------|
| | | | | | No. of pixels | Baseline fit | Polyn. degree | Correction |
| Nb | 269.706 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Ni | 231.604 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| P | 213.618 | axial | peak | 1 | 3 | ABC ¹ | auto | - |
| Rb | 780.027 | axial | peak | 5 | 3 | static | auto | - |
| Sb | 217.581 | axial | peak | 5 | 3 | ABC ¹ | auto | - |
| Sn | 189.927 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Sr | 407.771 | radial | peak | 1 | 3 | ABC ¹ | auto | - |
| Ta | 238.706 | axial | peak | 3 | 3 | ABC ¹ | auto | - |
| Ti | 334.941 | axial | peak | 1 | 3 | ABC ¹ | auto | - |
| Tl | 190.796 | axial | peak | 5 | 3 | ABC ¹ | auto | - |
| V | 292.401 | axial | peak | 1 | 3 | ABC ¹ | auto | - |
| W | 207.911 | axial | peak | 3 | 3 | ABC ¹ | auto | - |

¹ Automated Baseline Correction

² Attenuated radial observational view extends linear dynamic range into the percentage range

Results and Discussion

According to ISO 11885, the limits of detection (LODs) are calculated following the equation:

$$\text{LOD} = 3 s_0$$

where s_0 is the standard deviation of outlier-free results of at least 3 measurements of a reagent blank. The instrumental and method-specific detection and quantification limits, which consider the dilution factor of the digestion step, are shown in Table 4.

Table 4: Instrumental and method-specific limits of detection (LOD) and quantification (LOQ)

| Element | Line [nm] | Plasma view | Instrumental [$\mu\text{g/L}$] | | Method [mg/kg] | |
|---------|-----------|-------------|----------------------------------|-------|----------------|-------|
| | | | LOD | LOQ | LOD | LOQ |
| Al | 396.152 | radial | 4.16 | 12.50 | 2.08 | 6.25 |
| As | 188.979 | axial | 3.06 | 9.20 | 1.53 | 4.60 |
| Be | 313.042 | radial | 0.20 | 0.60 | 0.10 | 0.30 |
| Bi | 223.061 | axial | 3.71 | 11.10 | 1.85 | 5.55 |
| Ca | 315.887 | radial | 2.04 | 6.10 | 1.02 | 3.05 |
| Co | 228.615 | axial | 0.25 | 0.80 | 0.13 | 0.40 |
| Cr | 267.716 | axial | 0.12 | 0.40 | 0.06 | 0.20 |
| Cs | 894.347 | axial | 7.16 | 21.50 | 3.58 | 10.75 |
| Fe | 259.940 | radial | 0.55 | 1.70 | 0.28 | 0.85 |
| Ga | 294.364 | axial | 1.58 | 4.70 | 0.79 | 2.35 |

Table 4 (continued): Instrumental and method-specific limits of detection (LOD) and quantification (LOQ)

| Element | Line [nm] | Plasma view | Instrumental [$\mu\text{g/L}$] | | Method [mg/kg] | |
|---------|-----------|-------------|----------------------------------|-------|----------------|-------|
| | | | LOD | LOQ | LOD | LOQ |
| K | 766.491 | radial | 28.12 | 84.40 | 14.06 | 42.20 |
| Li | 670.791 | radial PLUS | 0.90 | 2.70 | 0.45 | 1.35 |
| Mg | 285.213 | radial | 0.52 | 1.60 | 0.26 | 0.80 |
| Mn | 293.931 | radial PLUS | 2.45 | 7.30 | 1.22 | 3.65 |
| Na | 589.592 | radial | 5.14 | 15.40 | 2.57 | 7.70 |
| Nb | 269.706 | axial | 0.58 | 1.80 | 0.29 | 0.90 |
| Ni | 231.604 | axial | 0.71 | 2.10 | 0.36 | 1.05 |
| P | 213.618 | axial | 7.69 | 23.10 | 3.84 | 11.55 |
| Rb | 780.027 | axial | 0.74 | 2.20 | 0.37 | 1.10 |
| Sb | 217.581 | axial | 6.72 | 20.10 | 3.36 | 10.05 |
| Sn | 189.927 | axial | 1.49 | 4.50 | 0.75 | 2.25 |
| Sr | 407.771 | radial | 0.01 | 0.02 | 0.00 | 0.01 |
| Ta | 238.706 | axial | 4.42 | 13.30 | 2.21 | 6.65 |
| Ti | 334.941 | axial | 0.07 | 0.20 | 0.03 | 0.10 |
| Tl | 190.796 | axial | 2.10 | 6.30 | 1.05 | 3.15 |
| V | 292.401 | axial | 0.19 | 0.60 | 0.09 | 0.30 |
| W | 207.911 | axial | 2.20 | 6.60 | 1.10 | 3.30 |

The analysis of three CRMs was used to perform method development and validation. Rather, the recoveries in the samples indicate which one of the two digestion procedure is most appropriate for which element. In the YS/T 509 series, the acidic digestion is performed on hot plate be using HF and H₂SO₄. This approach was adapted, scaled down to the microwave system and extended to include additional acids in order to stabilize all analytes appropriately in solution. Since lithium ores contain oxides of silica, aluminum and many of their variations or mixtures, digestion with varying mixtures of sulfuric, hydrofluoric, and hydrochloric acid is a requirement, in many cases with a subsequent complexation step with boric acid. Not surprisingly, this can possibly lead to numerous hardly soluble precipitates. Therefore, it was tested if an additional complexation step is required. Table 5 shows the certified values and recoveries of each element depending on the digestion procedure employing the complexation step of hydrofluoric acid (Proc. B) or leaving it out (Proc. A).

Table 5: Comparison of the reference values with recoveries in samples following sample preparation procedure without (Proc. A) and with (Proc. B) boric acid complexation step

| Element | OREAS 750 | | | OREAS 753 | | | OREAS 999 | | |
|---------|-------------------|----------------------|----------------------|-------------------|----------------------|----------------------|-------------------|----------------------|----------------------|
| | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] |
| Al | 54,200 | <u>63</u> | 93 | 82,200 | <u>28</u> | 100 | 107,700 | <u>21</u> | 103 |
| As | 13.3 | 102 | <u>158*</u> | 5.33 | 99 | <u>214*</u> | 5.36 | 111 | <u>222*</u> |
| Be | 37.6 | 106 | 98 | 118 | 93 | 103 | 49.8 | 88 | 99 |
| Bi | 1.00 | <MLD | <MLD | 2.2 | <MLQ | <MLQ | 2.11 | <MLQ | <MLQ |
| Ca | 8,280 | <u>74</u> | 95 | 1,130 | <u>22</u> | 108 | 4,500 | <u>32</u> | 96 |

Table 5 (continued): Comparison of the reference values with recoveries in samples following sample preparation procedure without (Proc. A) and with (Proc. B) boric acid complexation step

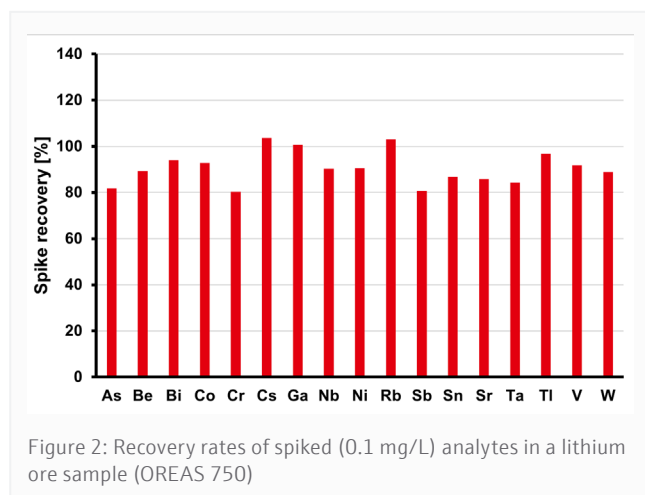
| Element | OREAS 750 | | | OREAS 753 | | | OREAS 999 | | |
|---------|-------------------|----------------------|----------------------|-------------------|----------------------|----------------------|-------------------|----------------------|----------------------|
| | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] | Certified [mg/kg] | Recovery Proc. A [%] | Recovery Proc. B [%] |
| Co | 3.99 | 117 | 103 | 0.96 | 92 | 94 | 4.95 | 91 | 94 |
| Cr | 27.6 | 98 | 104 | 20.8 | 94 | 109 | 81 | 105 | 104 |
| Cs | 22.6 | 95 | 108 | 64 | <u>74</u> | 102 | 88 | <u>71</u> | 117 |
| Fe | 16,700 | 95 | 92 | 8,390 | 89 | 97 | 16,200 | 91 | 94 |
| Ga | 13 | 110 | <u>270*</u> | 16.1 | 102 | <u>252*</u> | 82 | 105 | <u>135*</u> |
| K | 16,900 | 94 | 93 | 19,300 | 88 | 102 | 5,000 | <u>56</u> | 99 |
| Li | 2320 | 86 | <u>73</u> | 9,850 | 96 | 95 | 26,500 | 94 | 88 |
| Mg | 3150 | <u>22</u> | 97 | 110 | <u>12</u> | 102 | 4,100 | <u>9</u> | 98 |
| Mn | 380 | 97 | 92 | 740 | 98 | 102 | 1430 | 99 | 97 |
| Na | 15,300 | 95 | 91 | 21,600 | 89 | 90 | 6,930 | 83 | 94 |
| Nb | 21.3 | 101 | 100 | 36.3 | 97 | 95 | 75 | 93 | 92 |
| Ni | 11.4 | 105 | 90 | 10.8 | 106 | 89 | 47.5 | 103 | 94 |
| P | 700 | 105 | 92 | 1,110 | 105 | 95 | 160 | 101 | 93 |
| Rb | 254 | 51 | 97 | 612 | 97 | 110 | n.c. | - | - |
| Sb | 0.42 | <MLD | <MLD | 0.27 | <MLD | <MLD | 1.11 | <MLD | <MLD |
| Sn | 25.2 | 90 | 103 | 84 | 97 | 99 | 63 | 93 | 103 |
| Sr | 74 | <u>69</u> | 99 | 25.5 | <u>11</u> | 105 | 16.9 | <u>40</u> | 111 |
| Ta | 9.78 | 101 | 100 | 20 | 105 | 98 | 49 | 92 | 87 |
| Ti | 1,580 | 93 | 91 | 40 | <u>79</u> | <u>79</u> | 340 | 95 | 95 |
| Tl | 1.45 | <MLQ | <MLQ | 3.67 | <MLQ | <MLQ | 4.26 | <MLQ | <MLQ |
| V | 26.4 | 101 | <u>111*</u> | 1.16 | 103 | <u>315*</u> | 14.8 | 94 | <u>110*</u> |
| W | 5.46 | 92 | <u>72</u> | 5.62 | 94 | <u>81</u> | 6.97 | 93 | <u>72</u> |

* overestimation of analyte caused by spectral interferences originating from H_3BO_3 matrix

Basically, it can be stated that for most analytes it is irrelevant which of the two procedures is used for sample preparation. Only for Al, As, Ca, Cs, Ga, Mg, Sr, V, and W there are major deviations in recovery between the two methods. While spectral interferences (caused by the H_3BO_3 matrix) are responsible for the large differences for As, Ga, and V, it can be seen for the elements of the I and II main group as well as Al that the procedure with complexation of the hydrofluoric acid gives significantly better recoveries. This can be partially explained by the fact that the complexation step eliminates formation of insoluble fluoride precipitates (e.g., Al, Ca, and Mg). Additionally, stability in solution of certain elements (e.g., W) strongly depends on

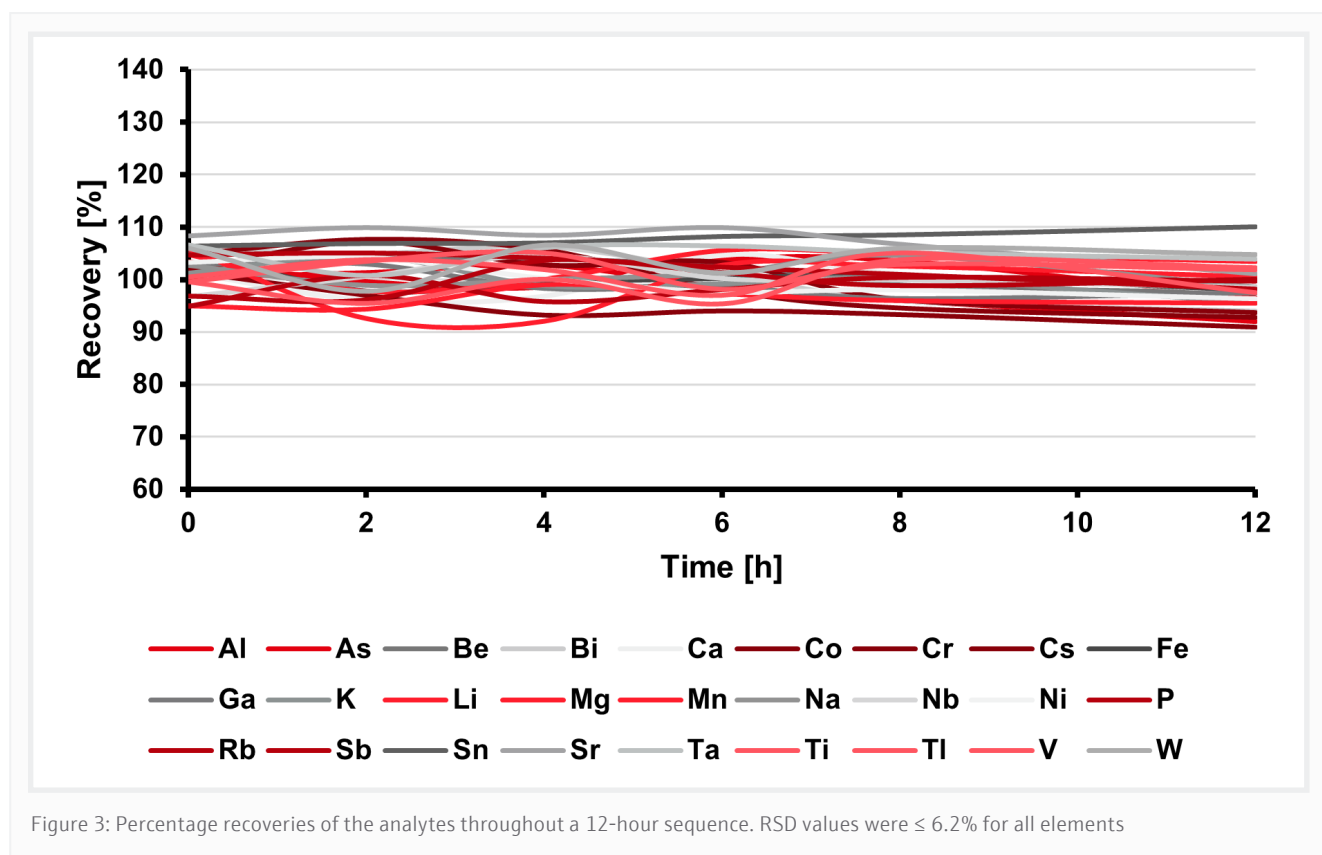
the availability of fluoride ions. If the more suitable of the two methods is chosen for the respective element, recovery rates between 86 and 111% are obtained for the majority of the elements.

Since the concentration of some trace elements in the reference materials were below the method-specific limit of quantification, one sample (OREAS 750, without HF complexation) was spiked with a low analyte concentration (0.1 mg/L) to check for accuracy and applicability of the overall method. Additionally, it was tested if possible matrix effects have influences on the signal intensity of pathfinder elements. Standard procedures, such as the EN ISO 11885,

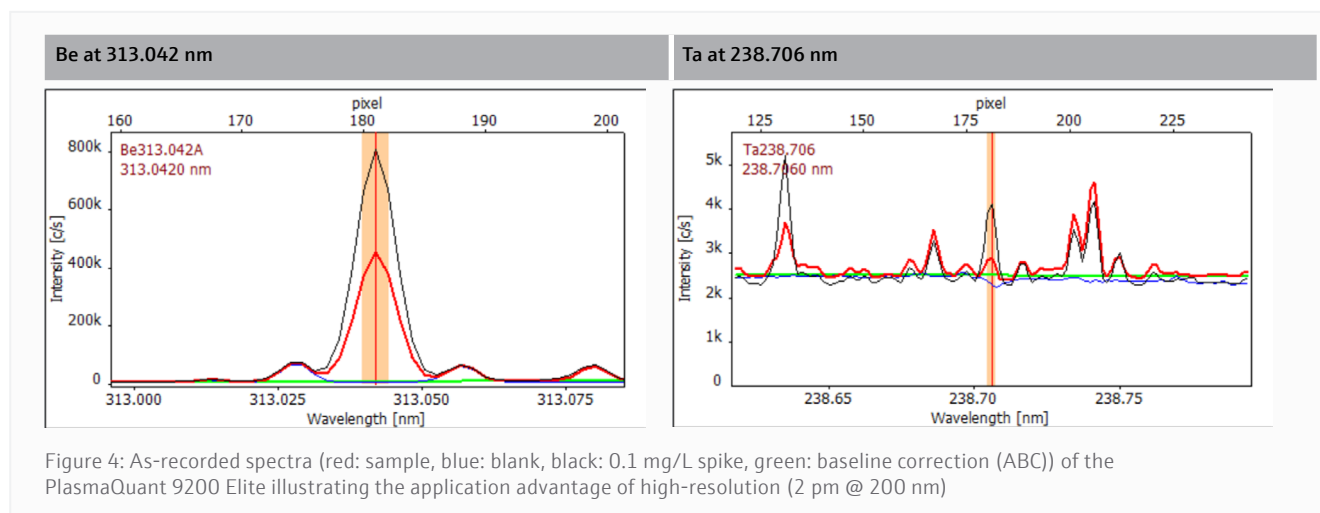


indicate that the recovery of the spiked analyte concentration must be within $\pm 20\%$ of the concentration equivalent added to the sample. Figure 2 shows the analyte recoveries which all were within a $\pm 20\%$ range proving the applicability of the method for the determination of pathfinder elements in the undiluted ore samples at low concentration levels.

Long term stability was investigated by monitoring the results of QC standard testing for twelve hours. This resulted in recoveries in the range of $\pm 10\%$ (see Figure 3). Relative standard deviations below 6.2% indicate a highly stable performance of the instrumentation throughout the 12 hours of measurement.



Quantification of traces in geological materials by ICP-OES is one of the most challenging analytical routines. Often containing large amounts of alumina, iron and silica, sulfur and refractory metals, etc., the high matrix contents of digested samples require for exceptional plasma robustness. This is particularly true when attempting to detect trace levels of pathfinder elements, while avoiding sample dilution. The vast number of emission lines arising from matrix elements further adds to the complexity, which can be resolved by high spectral resolution only. Due to the high resolution of the instrument (2 pm @ 200 nm), also severe interferences can be spectrally resolved (see Figure 4), resulting in the ability to analyze all targeted elements without any further mathematical correction algorithms.

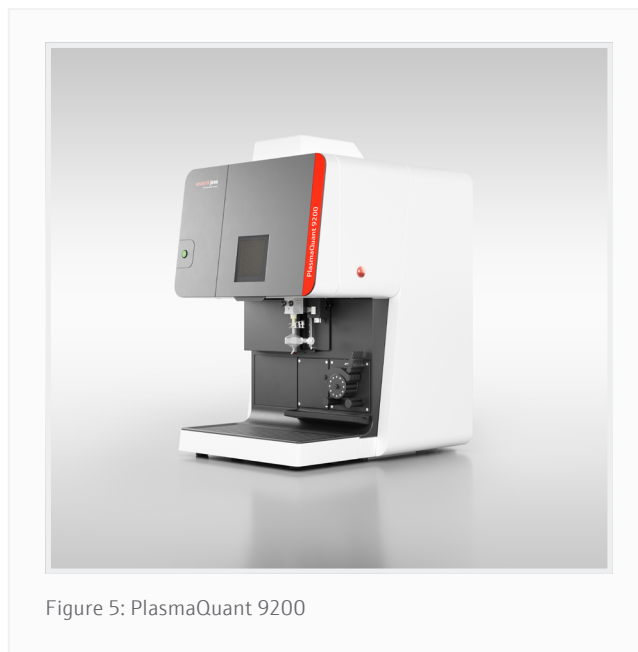


Summary

The presented method describes the use of highly sensitive and robust HR ICP-OES in a standard configuration for the analysis of lithium ore samples. The method validation was performed by analyzing a certified reference material as well as long-term stability analysis demonstrating the suitability of the PlasmaQuant 9200 ICP-OES systems for the elemental analysis of such matrices.

The major challenge comprises the analysis of elements over a wide concentration range (low $\mu\text{g/L}$ to high mg/L) in a single run. Trace elements (e.g., Be, Cs, Rb, and Ta) are analyzed along with major elements (e.g., Al, Fe, Li, and Na). This has been successfully demonstrated by the DualView PLUS feature of the PlasmaQuant 9200 series. Besides the common radial and axial plasma observation modes, the axial PLUS and radial PLUS modes offer further alternatives which attenuates the signal in the respective observational view. The described method uses radial and attenuated radial plasma observation to measure high levels of major elements alongside trace levels of pathfinder and targeted elements in a single measurement run. Herein, the method avoids the running of several dilutions to cover the entire concentration range. This helps especially in the analysis of a high concentration of lithium. The element can be quantified in the undiluted sample without having to dispense with the most sensitive and well-established analytical line at 670 nm.

The results indicate that microwave digestion can be used for all elements, significantly simplifying sample preparation. Depending on the analyte, it may be advantageous to



implement an additional step for the complexation of the hydrofluoric acid in the digestion protocol to improve the accuracy of the method.

It could be demonstrated that the requirements in terms of sensitivity, stability, and accuracy to perform the analysis of ore samples for pathfinder and targeted elements can be met with this proposed setup. The use of the PlasmaQuant 9200 series for analysis and the speedwave XPERT microwave digestion system for sample preparation is an excellent combination for the routine analysis of lithium ore samples.

Recommended device configuration

Table 6: Overview of devices, accessories, and consumables

| Article | Article number | Description |
|------------------------------------|----------------|---|
| PlasmaQuant 9200 Elite | 818-09201-2 | High resolution ICP-OES |
| speedwave XPERT | 819-5005000-2 | Microwave Pressure Digestion System |
| HF KIT for PlasmaQuant 9x00 series | 810-88007-0 | Sample introduction system for HF containing samples |
| Teledyne Cetac ASX 560 | 810-88015-0 | Autosampler with integrated rinse function |
| Teledyne Cetac ASXPress Plus | 810-88120-0 | Fully automated and easy-to-install 6 port injection valve and vacuum pump unit |

References

- [1] Robert J. Bowell et. al.; Classification and Characteristics of Natural Lithium Resources. *Elements* 2020; 16 (4): 259–264.
- [2] Balaram, V.; Sawant, S.S. Indicator Minerals, Pathfinder Elements, and Portable Analytical Instruments in Mineral Exploration Studies. *Minerals* 2022, 12, 394.
- [3] Renata Barros et al., Controls on chemical evolution and rare element enrichment in crystallising albite-spodumene pegmatite and wallrocks: Constraints from mineral chemistry, *Lithos*, 352–353, 2020

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